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**Scott et al.**

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(54) **DUAL FUEL TANK FOR LOCOMOTIVE AND MARINE APPLICATIONS**

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**B60K 15/03** (2006.01)

**B63B 11/04** (2006.01)

**B61C 17/02** (2006.01)

(52) **U.S. Cl.**

CPC ..... **B60K 15/03** (2013.01); **B60K 15/03006** (2013.01); **B61C 17/02** (2013.01); **B63B 11/04** (2013.01); **B60K 2015/03059** (2013.01); **B60K 2015/03105** (2013.01); **B60K 2015/03157** (2013.01); **B60K 2015/03309** (2013.01)

(58) **Field of Classification Search**

CPC ... **B60K 5/00**; **B60K 6/00**; **B60K 6/08**; **B60K 15/00**; **B60K 15/03**; **B63B 27/24**; **B63B 11/04**

See application file for complete search history.

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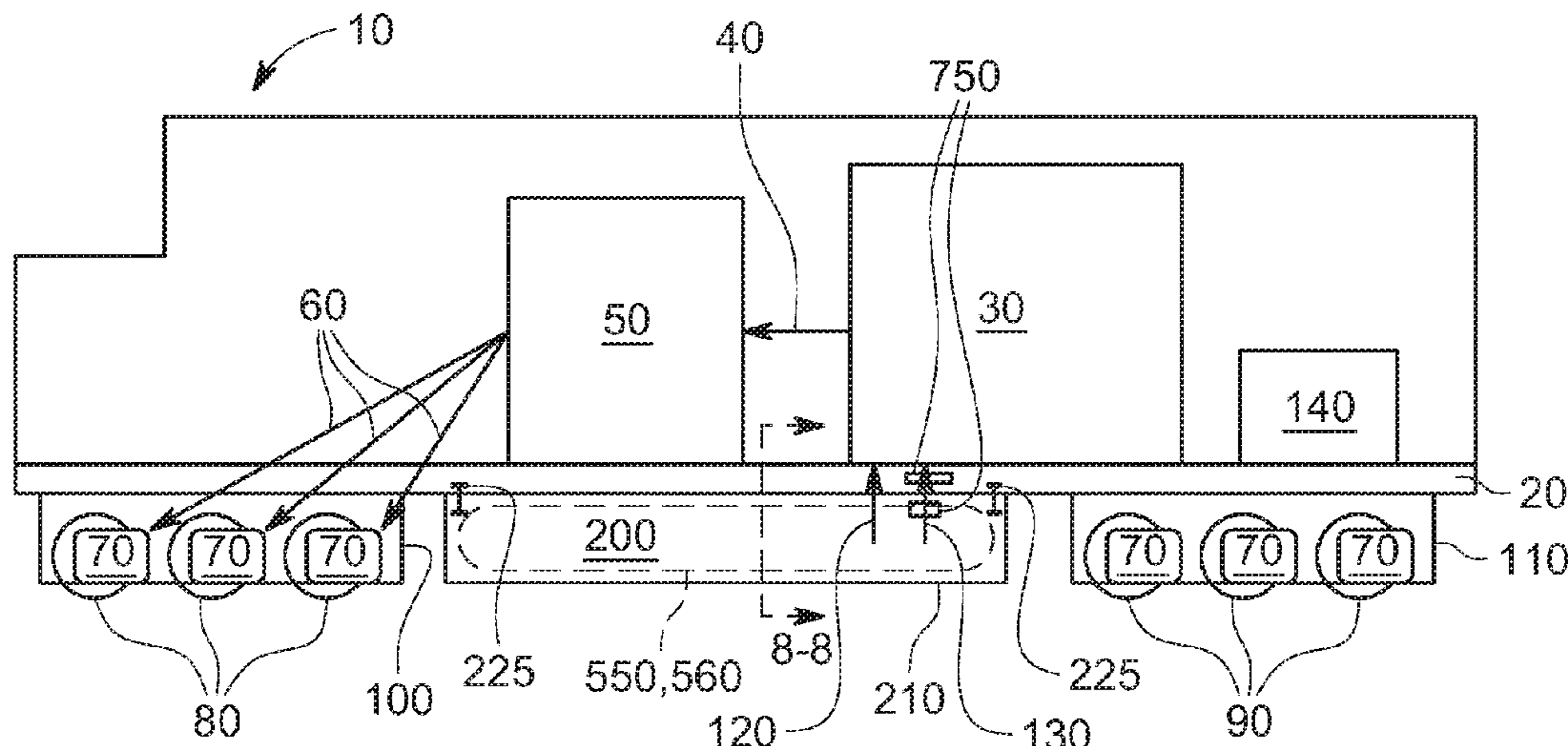
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(57) **ABSTRACT**

A dual-fuel tank houses one or more compressed natural gas (CNG) vessels and one or more diesel fuel vessels. The diesel fuel vessels are generally disposed laterally outwardly from the CNG vessels to provide a buffer that protects the CNG vessels from side impacts. The dual-fuel tank may be retrofit onto a diesel locomotive in place of the locomotive's diesel fuel tank to convert the locomotive into a dual-fuel locomotive. The dual-fuel tank may be provided in a ship.

**40 Claims, 10 Drawing Sheets**



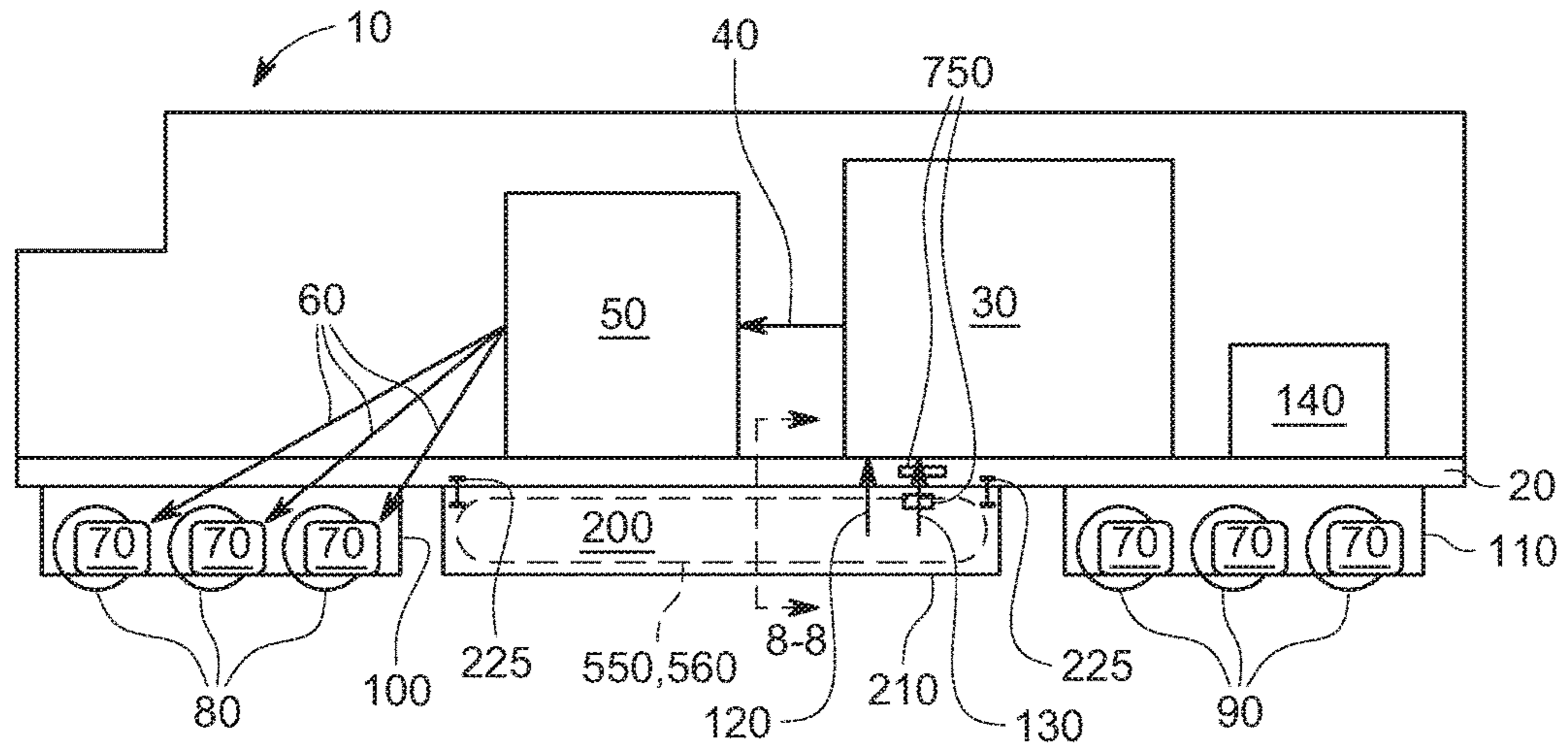


FIG. 1

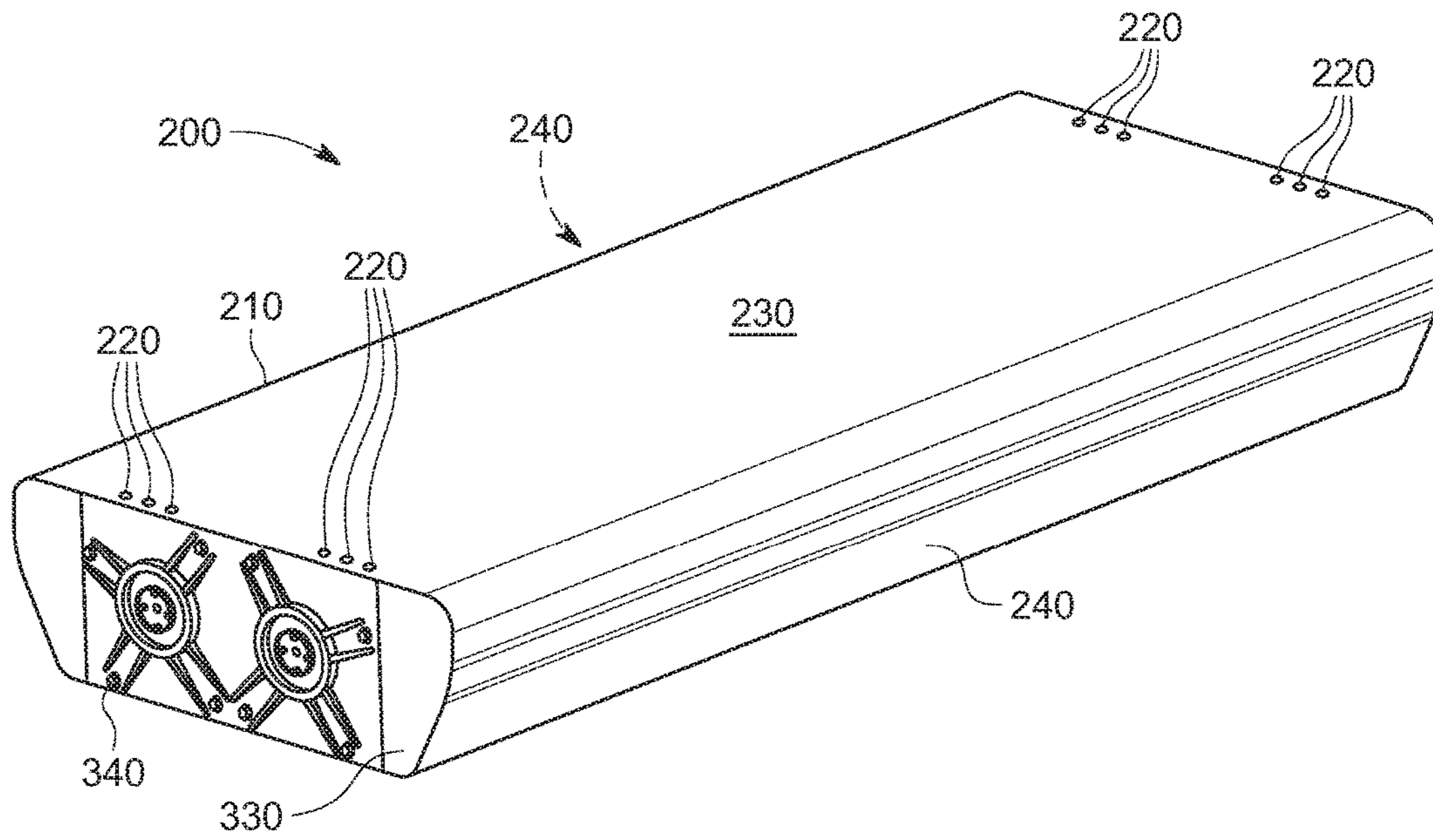


FIG. 2

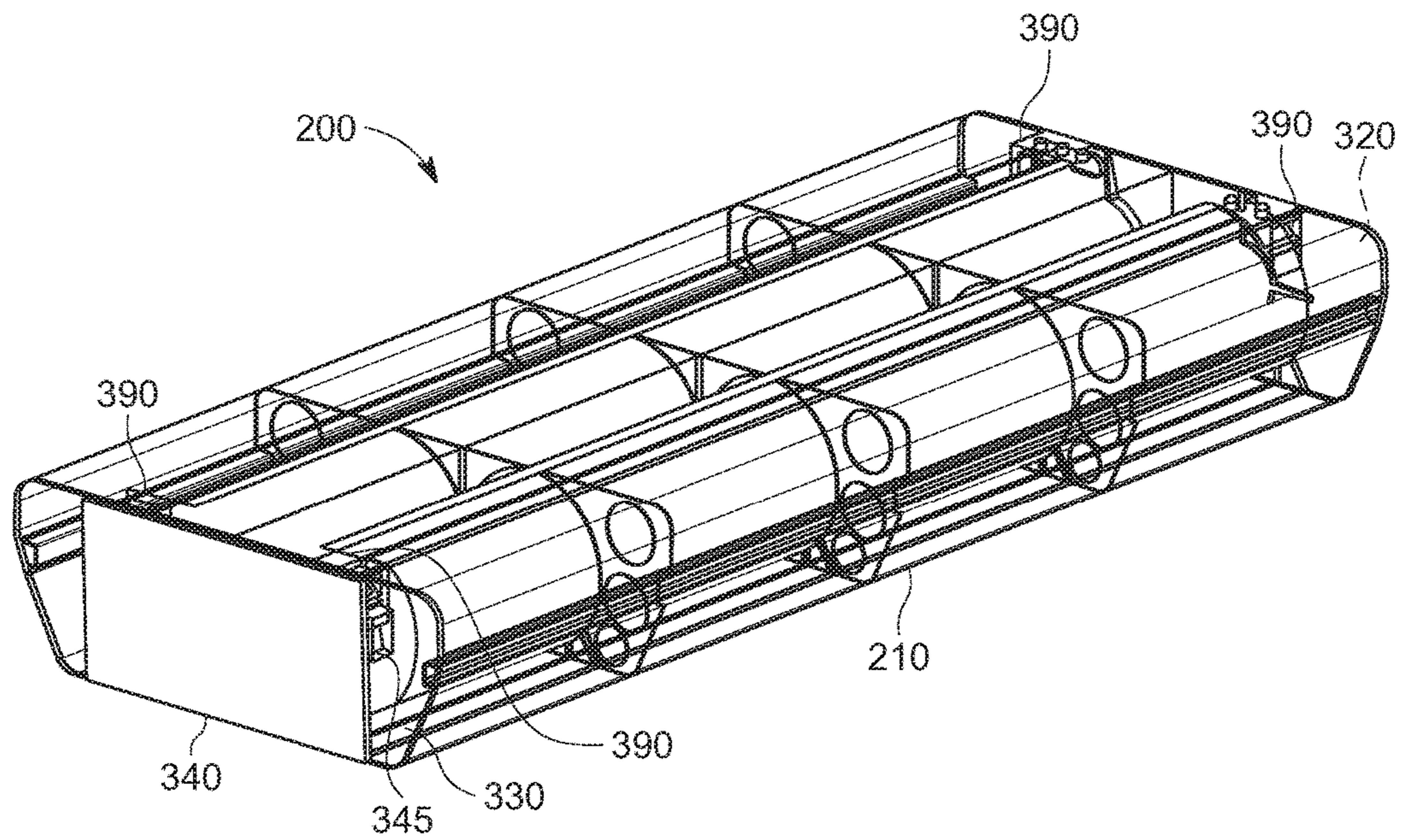


FIG. 3

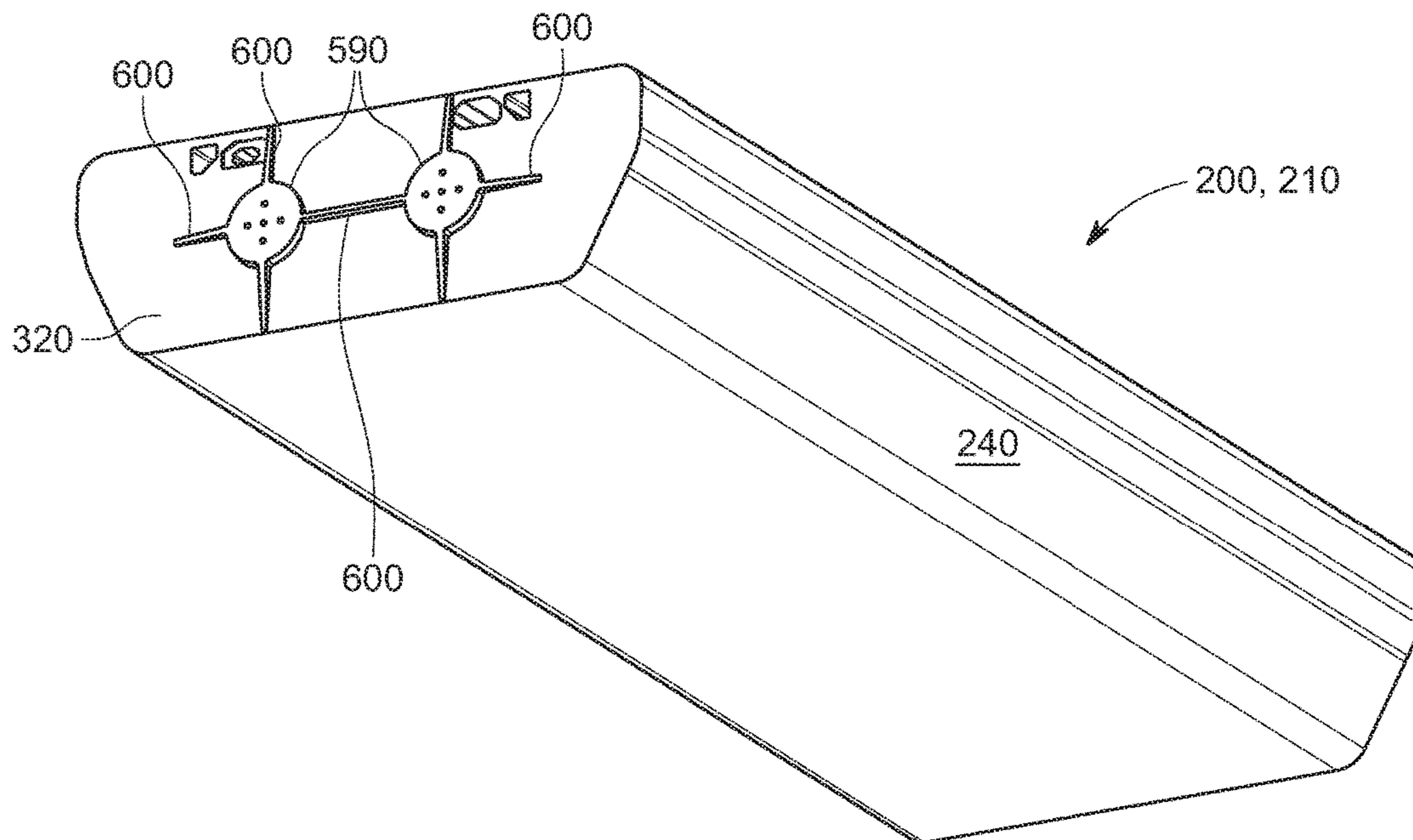


FIG. 4

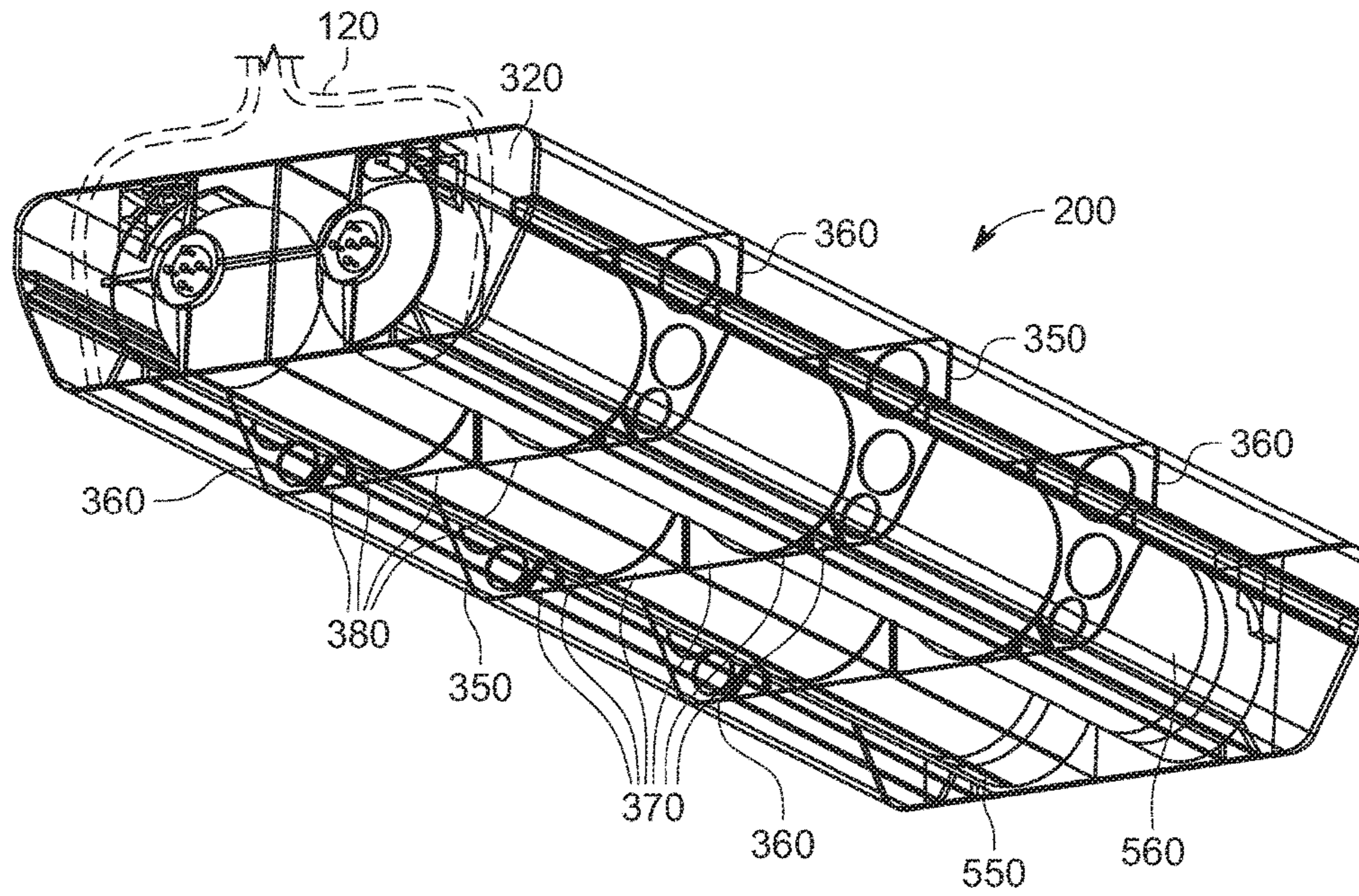


FIG. 5

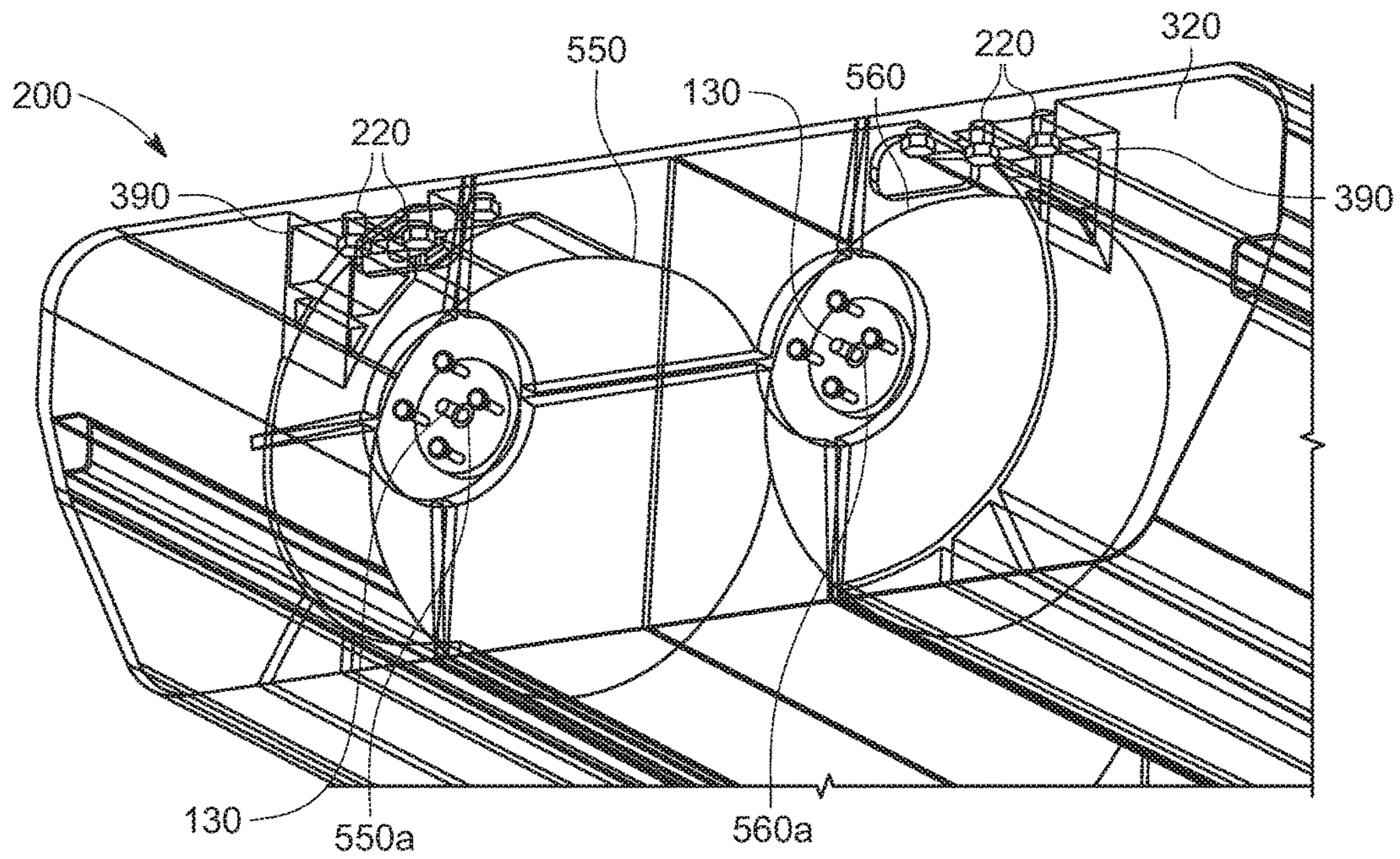


FIG. 6

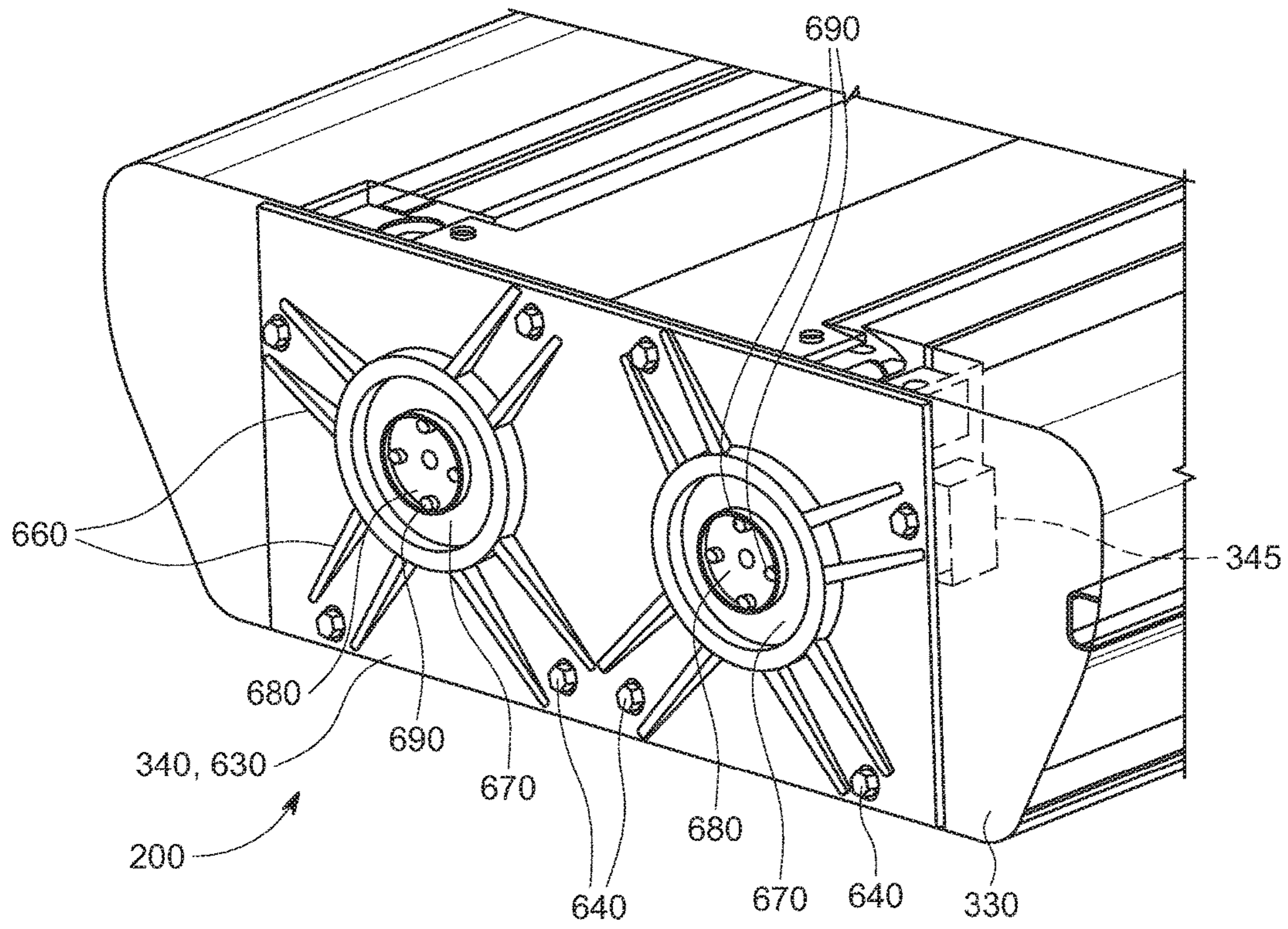


FIG. 7

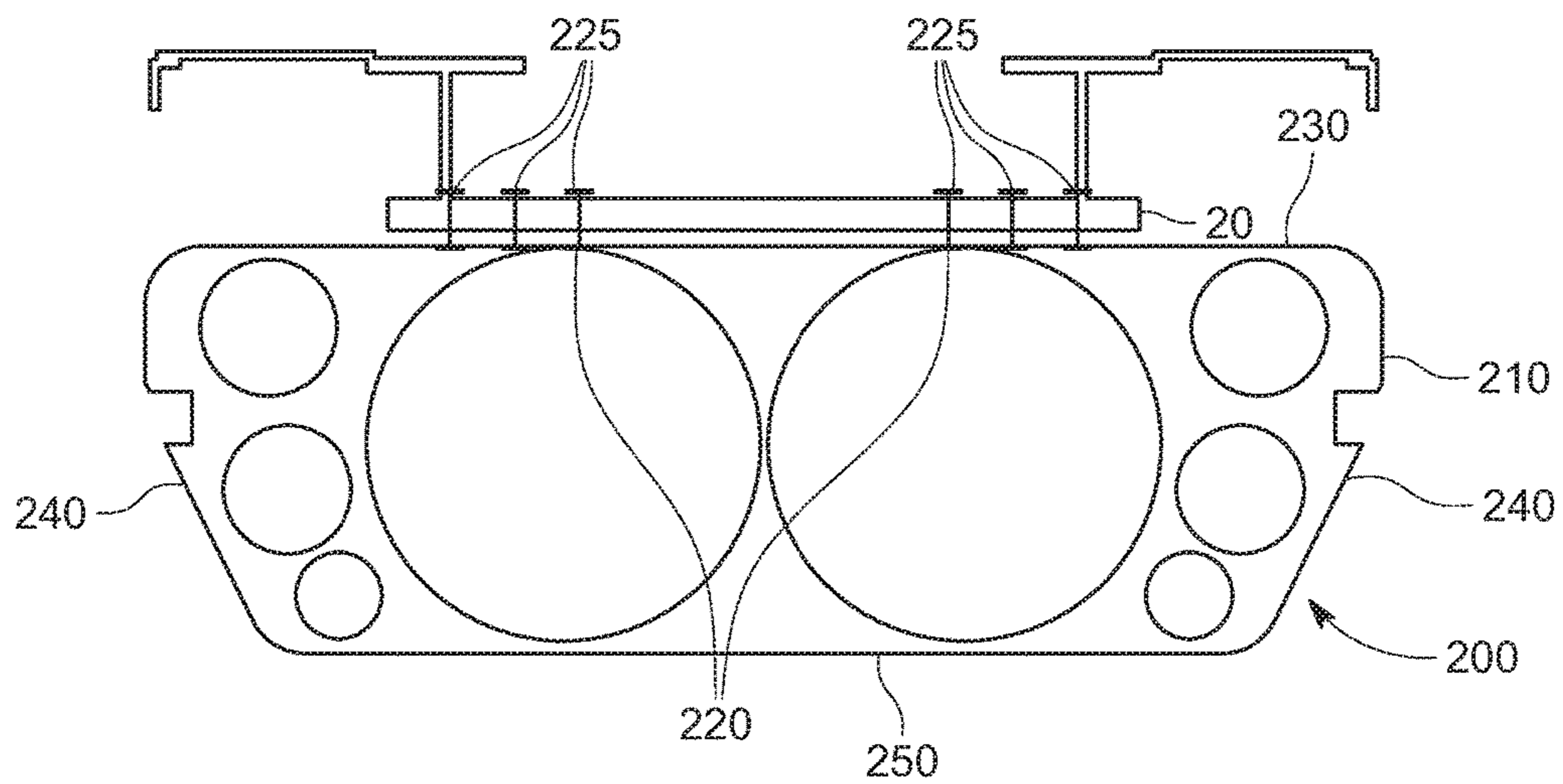


FIG. 8

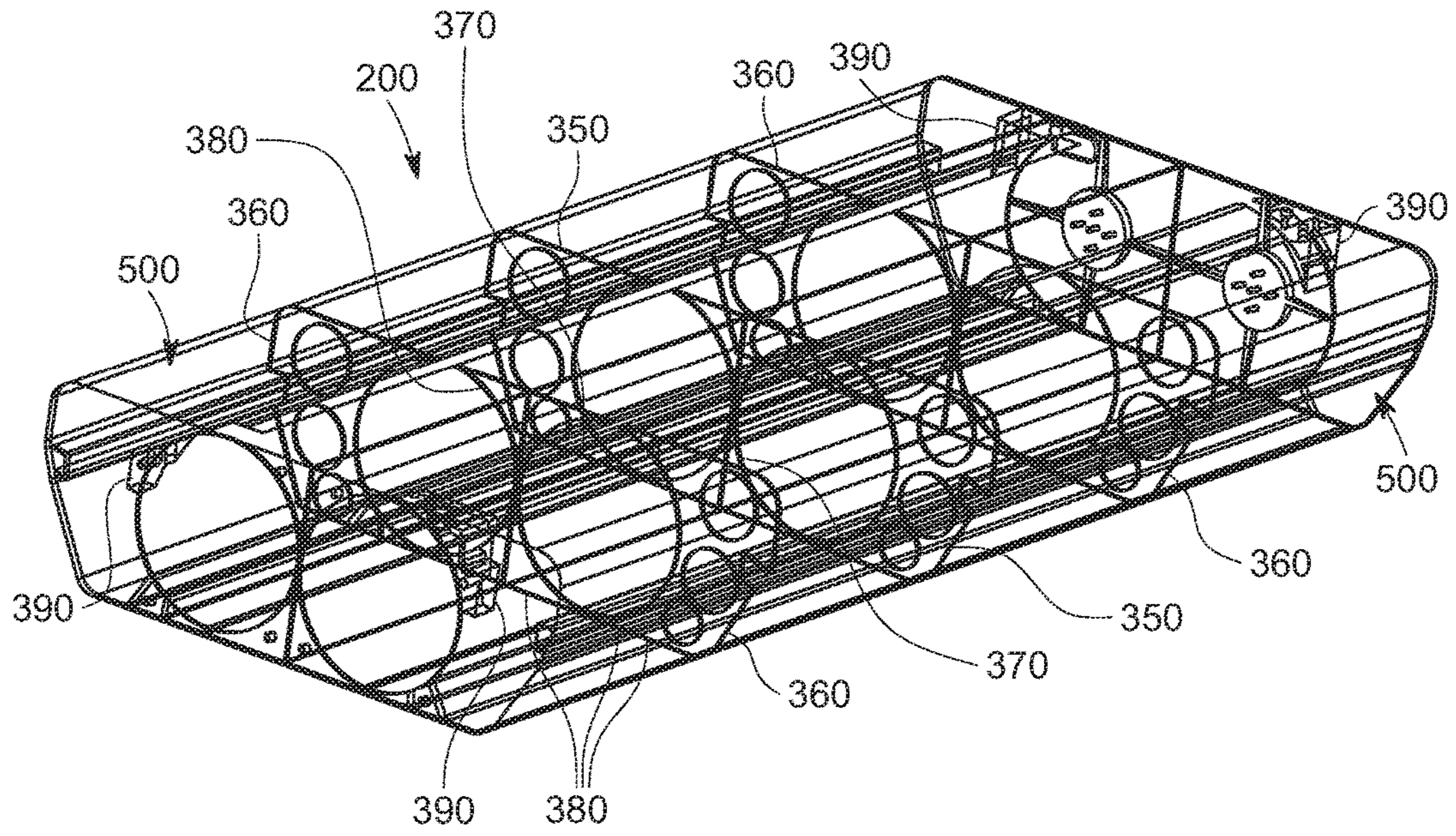


FIG. 9

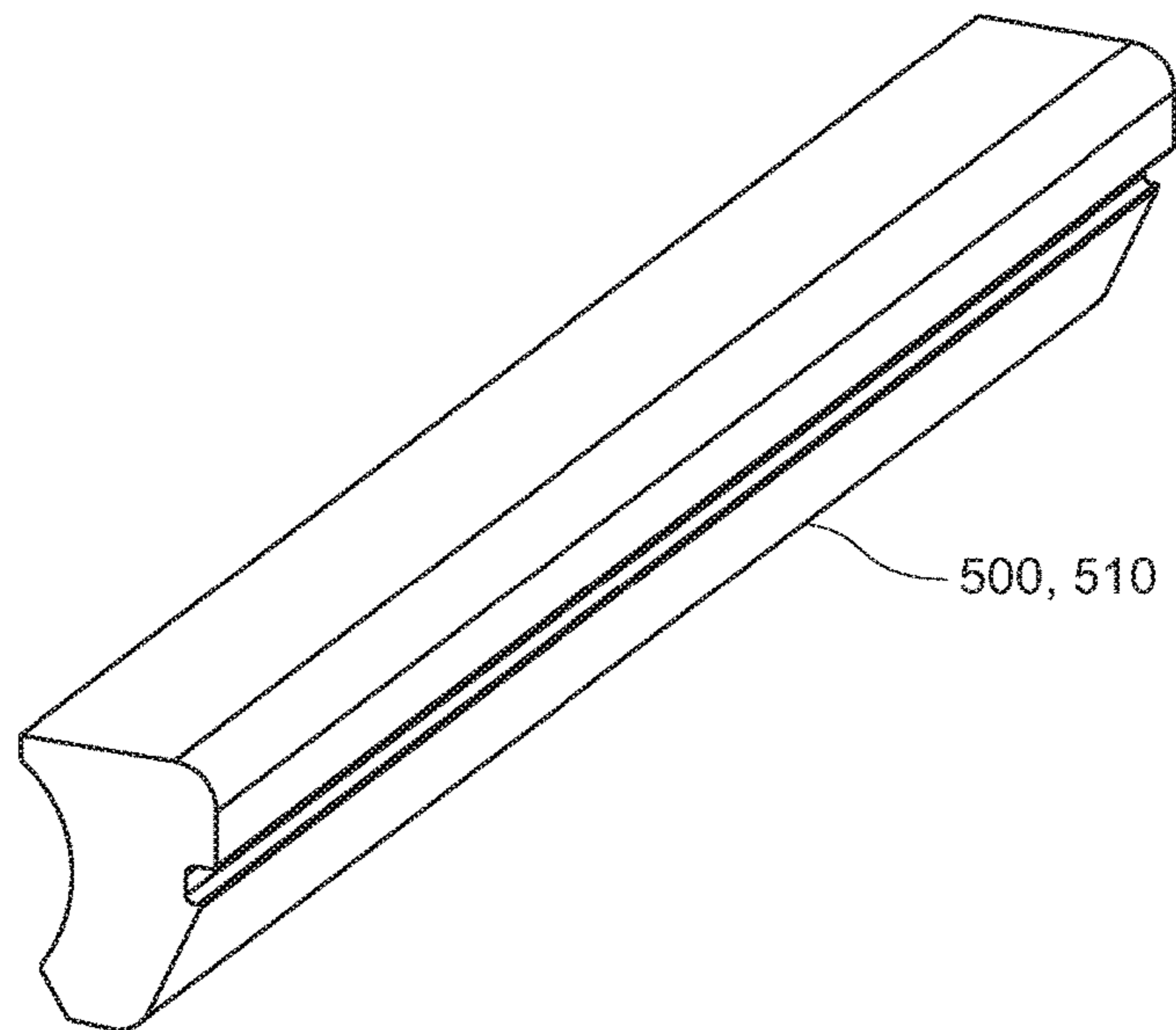


FIG. 10

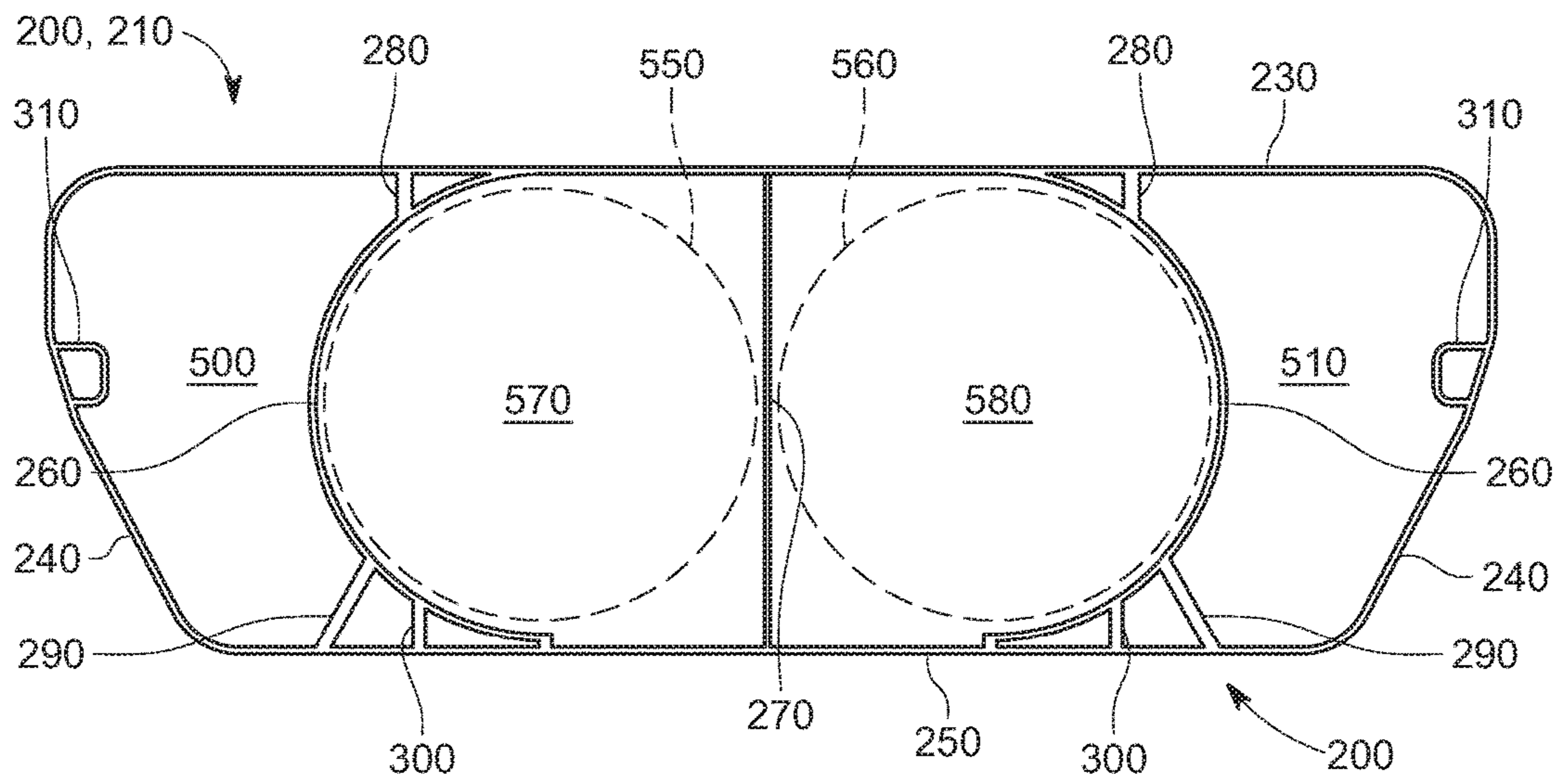


FIG. 11

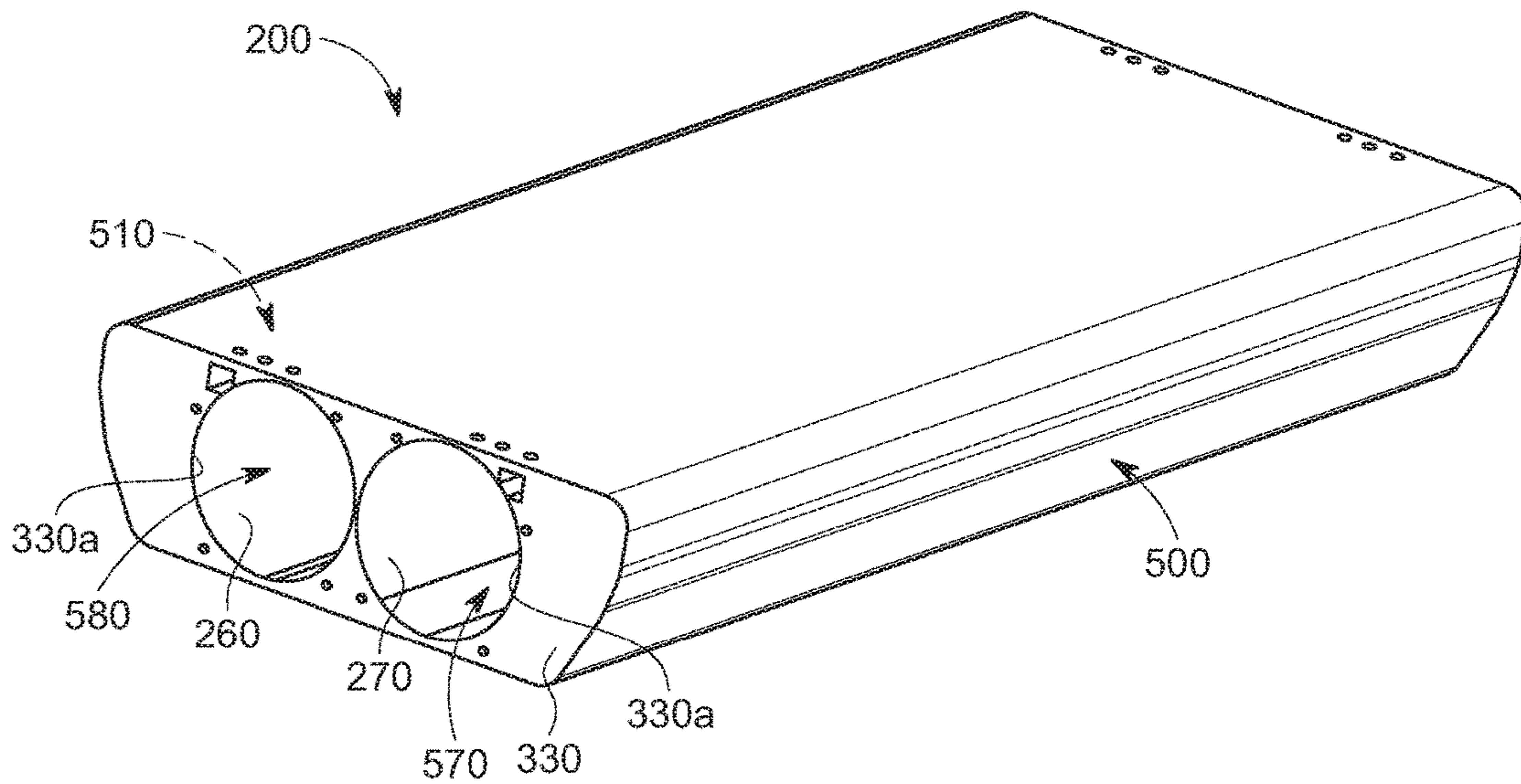


FIG. 12

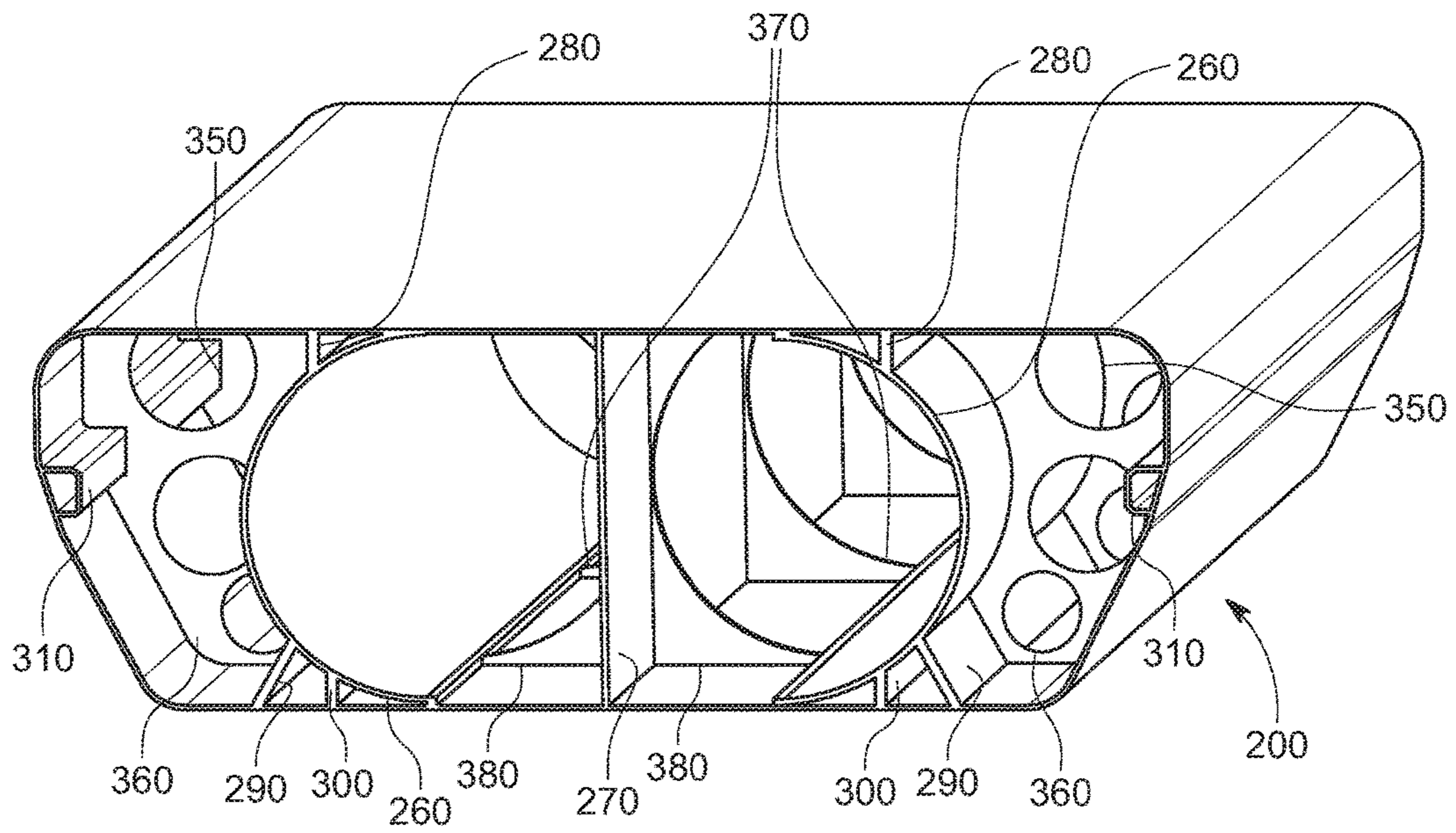


FIG. 13

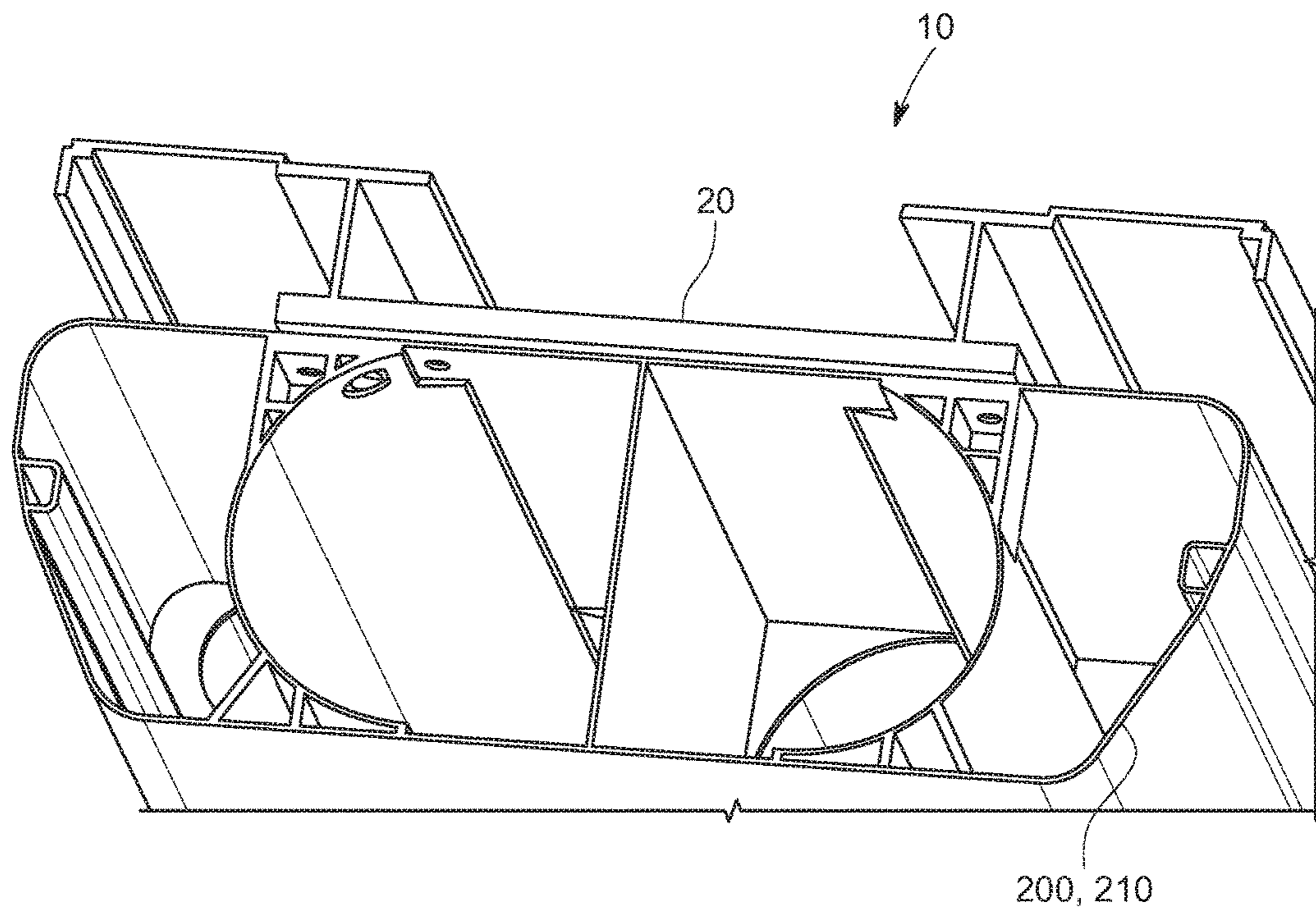


FIG. 14



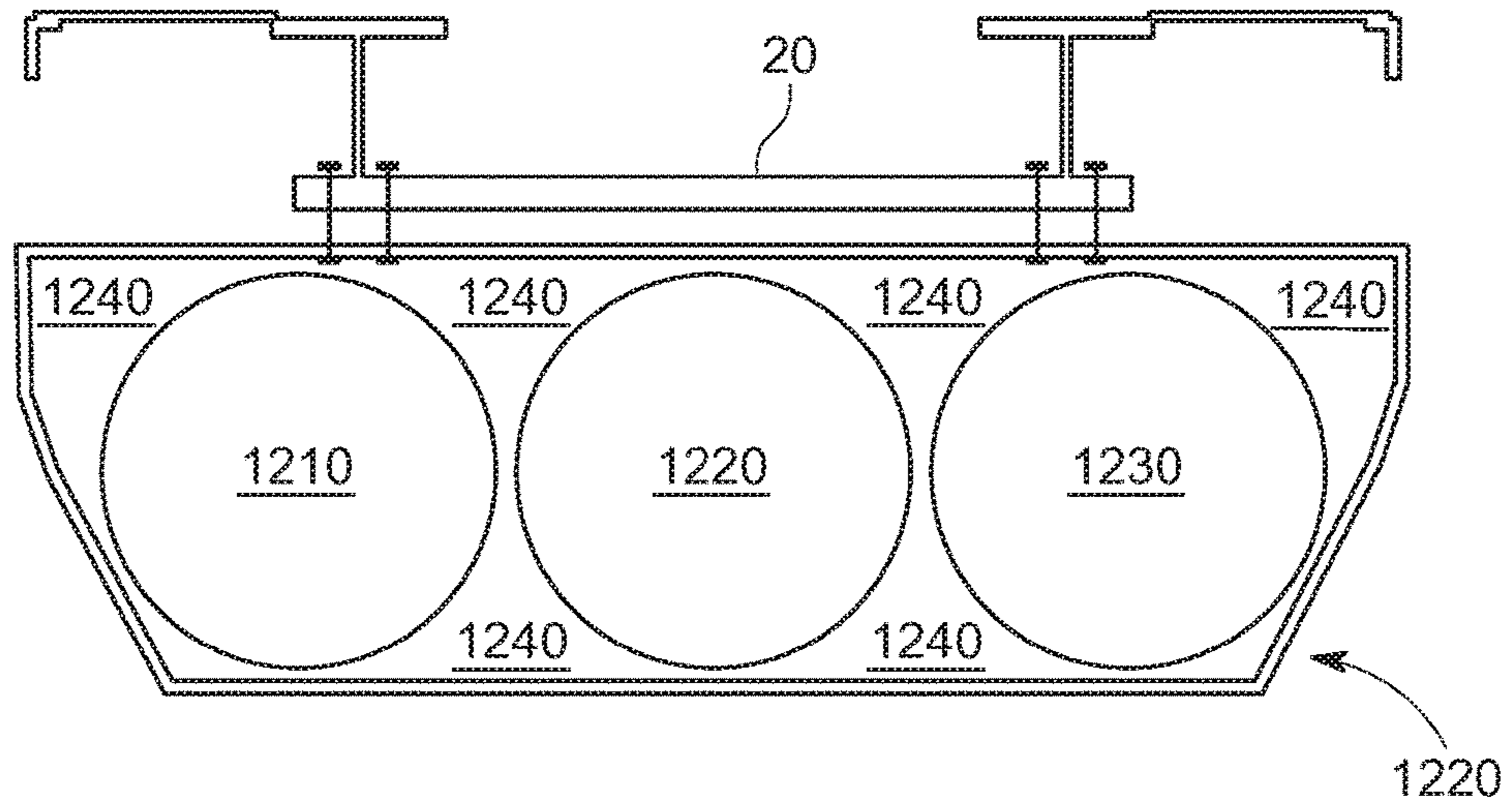


FIG. 15

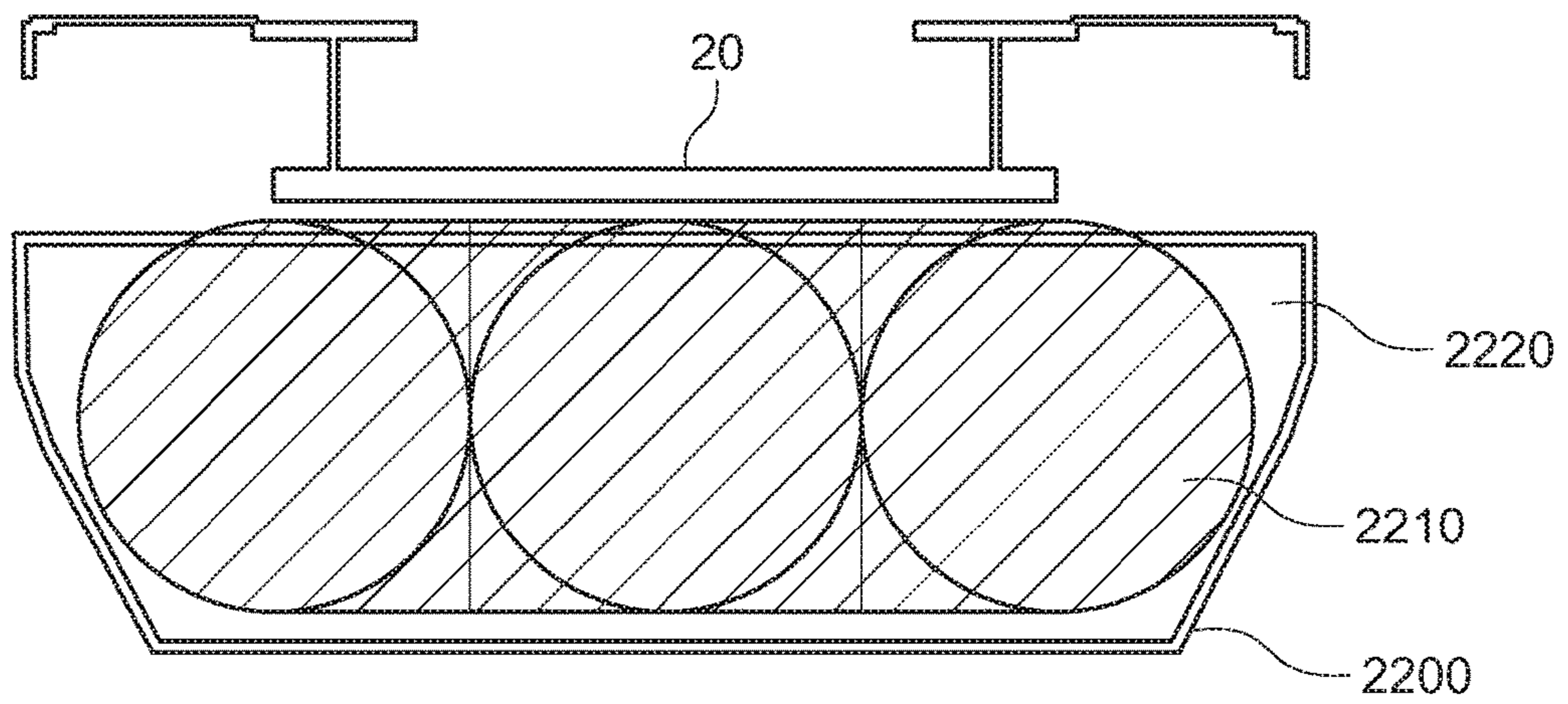


FIG. 16

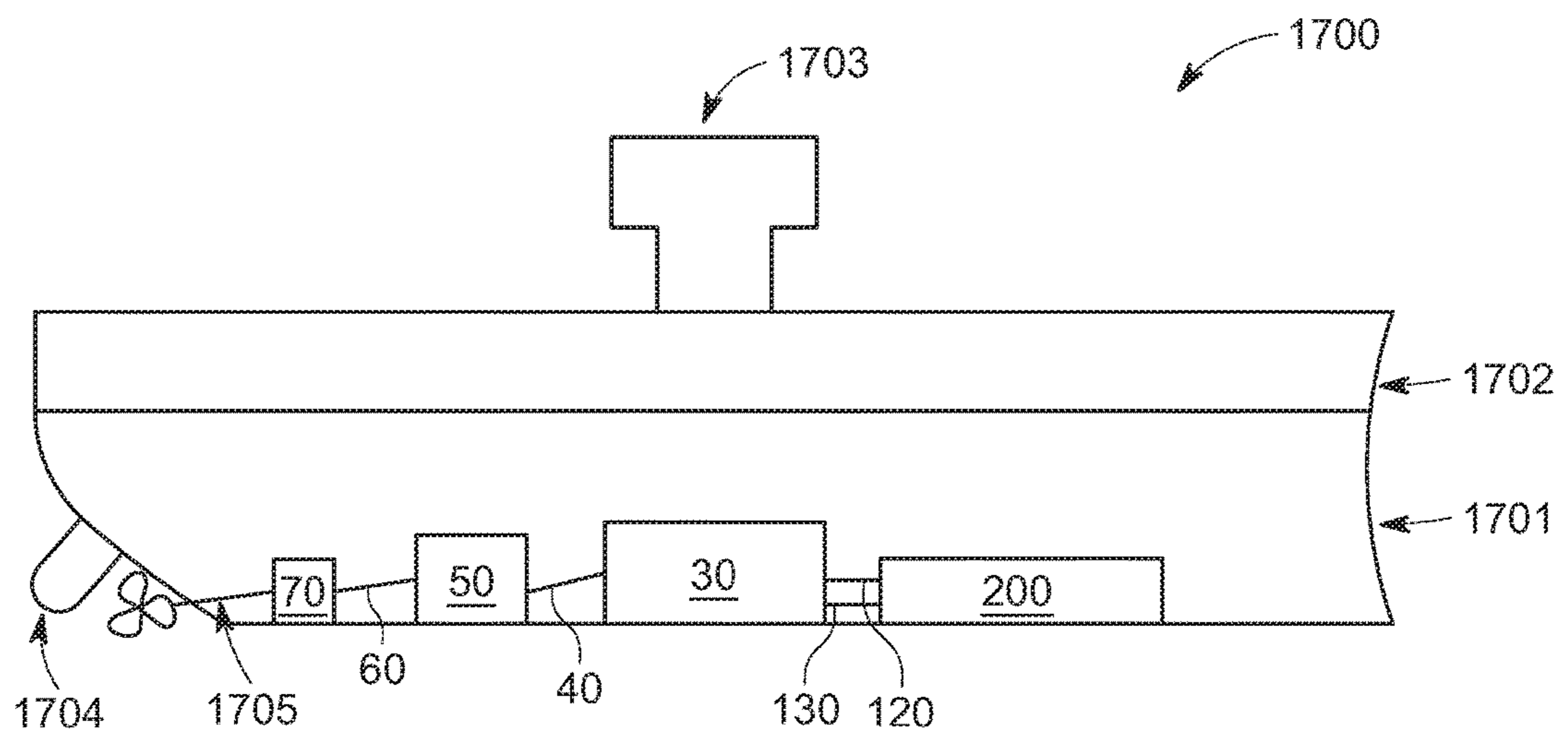


FIG. 17

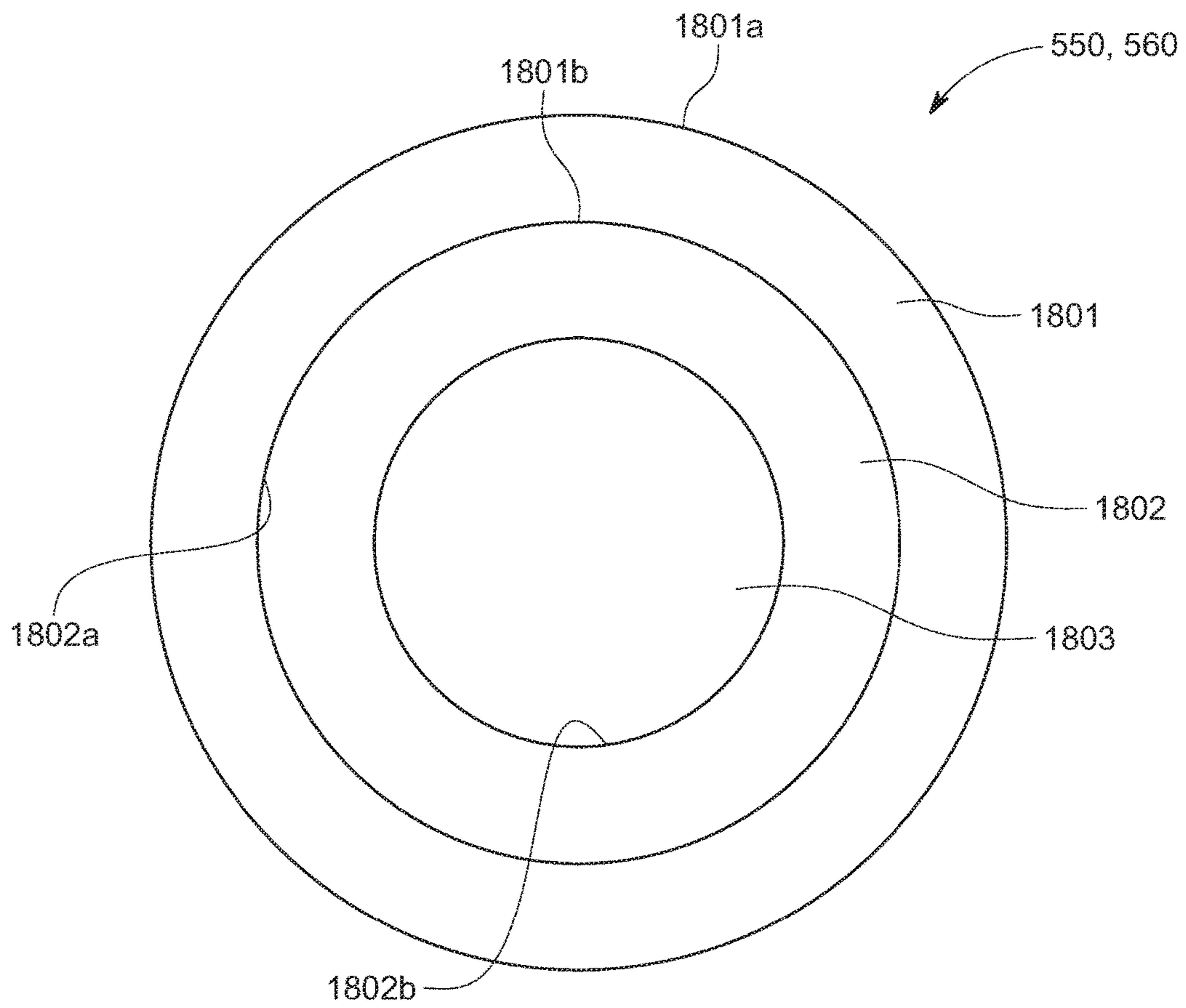


FIG. 18

## DUAL FUEL TANK FOR LOCOMOTIVE AND MARINE APPLICATIONS

### TECHNICAL FIELD

The present invention generally relates to fuel tanks for vehicles such as train locomotives and ships.

### BACKGROUND

Railroad locomotives such as diesel-electric locomotives transport goods and people on rails. Diesel-electric locomotives are powered by diesel engines that drive electric generators, which, in turn, drive electric motors that drive the locomotives' wheels. In various conventional diesel-electric locomotives, a diesel fuel tank is mounted to the locomotive between the front and rear wheels on an underside of the locomotive.

There has been increasing interest in using natural gas to power railroad locomotives, based on the relative price of natural gas and diesel fuel on a per unit of energy basis. Railroad locomotives have been designed to facilitate the use of a combination of diesel fuel and natural gas to drive the locomotive's engine(s) using the diesel cycle. Various conventional arrangements for dual fuel (e.g., natural gas and diesel fuel) configurations for locomotives call for a separate vehicle, also referred to as a fuel tender or a locomotive appurtenance, that contains the natural gas storage vessels in the form of liquid natural gas (LNG) or in the form of compressed natural gas (CNG) while the locomotive carries the conventional diesel fuel tank. The fuel tender connects to the locomotive to supply natural gas from the tender to the locomotive and its engine(s).

Marine vessels (e.g., large ships) are configured to combust multiple different fuels and will typically combust the cheapest fuel permitted in their location. More specifically, large ships typically combust heavy fuels (e.g., No. 6, which is also known as Bunker C, Furnace Fuel Oil, FFO, or Residual Fuel Oil) in unregulated zones (e.g., open sea). The large ships switch to cleaner fuels such as low sulfur diesel in regulated zones (e.g., near coastline).

To traverse through water, large ships include engines configured to burn the above fuels (these engines are referred to as diesel engines, although as stated above, the engines may be configured to burn, for example, Bunker C) that drive electric generators, which in turn, power the ship's propellers to push the ship through water. Conventional ships store the various fuels (e.g., Bunker C and low sulfur diesel) in separate vessels. In some cases, the engines of the large ships drive the propellers via a mechanical transmission and without use of intermediate electric generators.

### SUMMARY

One or more non-limiting embodiments provide a dual-fuel railroad locomotive with both diesel and natural gas storage compartments on the locomotive itself. According to various embodiments, the dual-fuel locomotive's engines are powered by diesel and natural gas that is supplied from the fuel compartments that are mounted to and supported by the locomotive itself (as opposed to a separate tender). In this manner, according to various embodiments, the dual-fuel locomotive may be operated without an additional tender.

One or more non-limiting embodiments provide a dual-fuel railroad locomotive that includes: a chassis; a plurality of front railroad wheels mounted to the chassis; a plurality

of rear railroad wheels mounted to the chassis; a dual-fuel diesel engine supported by the chassis and operatively connected to the front and rear wheels to drive the front and rear wheels to propel the locomotive along a railroad track; and a dual-fuel tank mounted to the chassis between the front and the rear wheels. The dual-fuel tank includes a frame that mounts the dual-fuel tank to the chassis, at least one liquid fuel vessel supported by the frame, and at least one pressurized fuel vessel supported by the frame.

According to one or more embodiments, the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel.

According to one or more embodiments, the at least one liquid fuel vessel extends laterally outwardly farther than any portion of the at least one pressurized fuel vessel.

According to one or more embodiments, the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts.

According to one or more embodiments, the at least one liquid fuel vessel comprises at least one diesel fuel vessel.

According to one or more embodiments, the at least one pressurized fuel vessel comprises at least one compressed natural gas vessel.

According to one or more embodiments, the locomotive complies with U.S. Federal Railway Administration and Association of American Railroads requirements S-580 & S-5506.

One or more non-limiting embodiments provide a method of converting a railroad locomotive into a dual fuel locomotive, the method including: removing a single-fuel tank from the railroad locomotive; and mounting a dual-fuel tank to the railroad locomotive in place of the single-fuel tank. The dual-fuel tank includes (1) a frame that mounts the dual-fuel tank to the chassis, (2) at least one liquid fuel vessel supported by the frame, and (3) at least one pressurized fuel vessel supported by the frame.

According to one or more embodiments, the method also includes after said mounting, operatively connecting the first and second compartments to the railroad locomotive so that the locomotive can be powered by fuel in the first and second compartments.

According to one or more embodiments, the first type of fuel comprises diesel fuel and the first compartment comprises a diesel fuel compartment.

According to one or more embodiments, the second type of fuel comprises natural gas and the second compartment comprises a natural gas storage compartment.

According to one or more embodiments, the second type of fuel comprises compressed natural gas and the natural gas storage compartment comprises a compressed natural gas storage vessel.

According to one or more embodiments, the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel after said mounting.

According to one or more embodiments, the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts after said mounting.

One or more non-limiting embodiments provide a dual-fuel railroad locomotive comprising: a chassis; a plurality of railroad wheels mounted to the chassis; a dual-fuel diesel cycle engine supported by the chassis and operatively connected to the wheels to drive the wheels to propel the locomotive along a railroad track; a dual-fuel tank mounted

to the chassis, the dual-fuel tank including: at least one liquid fuel vessel, and at least one pressurized fuel vessel.

According to one or more embodiments, the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel.

According to one or more embodiments, the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts.

According to one or more embodiments, the at least one liquid fuel vessel extends laterally outwardly farther than any portion of the at least one pressurized fuel vessel.

According to one or more embodiments, the at least one liquid fuel vessel includes at least one diesel fuel vessel.

According to one or more embodiments, the at least one pressurized fuel vessel includes at least one compressed natural gas vessel.

According to one or more embodiments, the at least one liquid fuel vessel is a void at least partially defined by a frame of the chassis.

One or more non-limiting embodiments provide a method of converting a railroad locomotive into a dual fuel locomotive, the method comprising: removing a single-fuel tank from the railroad locomotive; mounting a dual-fuel tank to the railroad locomotive in place of the single-fuel tank, the dual-fuel tank including: at least one liquid fuel vessel and at least one pressurized fuel vessel.

According to one or more embodiments, the method includes after said mounting, operatively connecting the first and second compartments to the railroad locomotive so that the locomotive can be powered by fuel in the first and second compartments.

According to one or more embodiments, the at least one liquid fuel vessel includes diesel fuel.

According to one or more embodiments, the at least one pressurized fuel vessel includes natural gas.

According to one or more embodiments, the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel after said mounting.

According to one or more embodiments, the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts after said mounting.

One or more non-limiting embodiments provide a dual-fuel tank comprising: a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels; wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame.

According to one or more embodiments, the liquid fuel vessels are voids at least partially defined by the frame.

According to one or more embodiments, the voids are at least partially defined by curved internal plates longitudinally extending inside the frame.

According to one or more embodiments, the curved internal plates are C-shaped and form a barrier between the liquid fuel vessels and the pressurized fuel vessels.

According to one or more embodiments, the tank includes at least one fuel line in fluid communication with each of the vessels, and at least one of the fuel lines includes an electric heater configured to heat the fluid flowing therethrough.

According to one or more embodiments, the frame includes a first end plate and a second end plate and both of the first end plate and the second end plate support the pressurized fuel vessels.

According to one or more embodiments, the first end plate and the second end plate cooperate to suspend at least one of the pressurized fuel vessels inside of the frame such that said pressurized fuel vessel is only supported by the first end plate and the second end plate.

According to one or more embodiments, the first end plate defines at least one longitudinally extending central ring void.

According to one or more embodiments, the tank includes a slider ring slideably received in the at least one longitudinally extending central rings void, the slider ring being fixed to an end of one of the pressure vessels.

According to one or more embodiments, at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer.

According to one or more embodiments, the non-sulfur reactive layer is a winding that includes a cross-weave of aramid fibers and fiberglass.

According to one or more embodiments, the winding excludes carbon-fiber.

According to one or more embodiments, the at least one of the pressurized vessels includes a non-sulfur reactive insulator encasing the non-sulfur reactive layer.

According to one or more embodiments, a vehicle includes an engine and the tank, and the engine is configured to draw and combust fuel from the liquid fuel vessels and the pressurized fuel vessels.

According to one or more embodiments, the first end plate and the second end plate cooperate to suspend at least one of the pressurized fuel vessels inside of the frame such that said pressurized fuel vessel is only supported by the first end plate and the second end plate.

According to one or more embodiments, the first end plate defines at least one longitudinally extending central ring void.

According to one or more embodiments, the tank includes a slider ring slideably received in the at least one longitudinally extending central rings void, the slider ring being fixed to an end of one of the pressure vessels.

According to one or more embodiments, at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer.

According to one or more embodiments, the non-sulfur reactive layer is a winding that includes a cross-weave of aramid fibers and fiberglass.

According to one or more embodiments, the winding excludes carbon-fiber.

According to one or more embodiments, the at least one of the pressurized vessels includes a non-sulfur reactive insulator encasing the non-sulfur reactive layer.

According to one or more embodiments, a vehicle includes an engine and the tank and the engine is configured to draw and combust fuel from the liquid fuel vessels and the pressurized fuel vessels.

According to one or more embodiments, the engine is configured to vary the ratio of combusted liquid fuel to the ratio of combusted pressurized fuel.

According to one or more embodiments, a ship includes a dual-fuel engine configured to draw both liquid fuel and pressurized fuel from the tank.

According to one or more embodiments, the liquid fuel vessels include Bunker C fuel.

According to one or more embodiments, the ship includes heaters configured to lower the viscosity of the liquid fuel while the liquid fuel is drawn from the tank to the dual-fuel engine.

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According to one or more embodiments, the non-sulfur reactive layer is a winding that includes a cross-weave of aramid fibers and fiberglass, the winding has an inner portion and an outer portion, and a density of the inner portion is different than a density of the outer portion.

These and other aspects of various embodiments of the present invention, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. In one embodiment of the invention, the structural components illustrated herein are drawn to scale. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention. In addition, it should be appreciated that structural features shown or described in any one embodiment herein can be used in other embodiments as well. As used in the specification and in the claims, the singular form of “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise.

All closed-ended (e.g., between A and B) and open-ended (greater than C) ranges of values disclosed herein explicitly include all ranges that fall within or nest within such ranges. For example, a disclosed range of 1-10 is understood as also disclosing, among other ranged, 2-10, 1-9, 3-9, etc.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be made to embodiments shown in the following drawings. The components in the drawings are not necessarily to scale and related elements may be omitted, or in some instances proportions may have been exaggerated, so as to emphasize and clearly illustrate the novel features described herein. In addition, system components can be variously arranged, as known in the art. Further, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. 1 is a diagrammatic side view of a railroad locomotive according to a non-limiting embodiment of the present invention.

FIG. 2 is a top perspective view of a dual-fuel tank of the locomotive in FIG. 1 and/or a ship.

FIG. 3 is a partially transparent top perspective view of the dual-fuel tank in FIG. 2.

FIG. 4 is a bottom perspective view of the dual-fuel tank in FIG. 2.

FIG. 5 is a bottom partially transparent perspective view of the dual-fuel tank in FIG. 2.

FIG. 6 is a close-up partial bottom partially transparent perspective view of the dual-fuel tank in FIG. 2.

FIG. 7 is a close-up partial top partially transparent perspective view of the dual-fuel tank in FIG. 2.

FIG. 8 is a partial diagrammatic cut-away view of the locomotive in FIG. 1, taken along the line 8-8 in FIG. 1.

FIG. 9 is a transparent, wireframe bottom perspective view of the dual-fuel tank in FIG. 2.

FIG. 10 is a top perspective view of the general shape of the interior compartment of a diesel fuel vessel of the dual-fuel tank in FIG. 2.

FIG. 11 is a diagrammatic end view showing the location of the fuel tanks of the dual-fuel tank in FIG. 2 and illustrating structural features of a tank frame.

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FIG. 12 is a top perspective view of the dual-fuel tank of FIG. 2 with the end plate and natural gas tanks removed.

FIG. 13 is a partial top perspective cut-away view of the dual-fuel tank of FIG. 2 with the end plate and natural gas tanks removed.

FIG. 14 is a partial bottom perspective cut-away view of the locomotive of FIG. 1.

FIG. 15 is a diagrammatic cut-away view of a locomotive with a dual-fuel tank according to an alternative embodiment.

FIG. 16 is a diagrammatic cut-away view of a locomotive with a dual-fuel tank according to an alternative embodiment.

FIG. 17 is a diagrammatic side view of a ship according to a non-limiting embodiment of the present invention.

FIG. 18 is a cross sectional view of a vessel for storing a compressed gas, such as CNG. This vessel may be part of the dual-fuel tank of FIG. 2.

#### DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

While the invention may be embodied in various forms, there are shown in the drawings, and will hereinafter be described, some exemplary and non-limiting embodiments, with the understanding that the present disclosure is to be considered an exemplification of the invention and is not intended to limit the invention to the specific embodiments illustrated.

In this application, the use of the disjunctive is intended to include the conjunctive. The use of definite or indefinite articles is not intended to indicate cardinality. In particular, a reference to “the” object or “a” and “an” object is intended to denote also one of a possible plurality of such objects. Further, the conjunction “or” may be used to convey features that are simultaneously present instead of mutually exclusive alternatives. In other words, the conjunction “or” should be understood to include “and/or”.

FIG. 1 illustrates a dual-fuel railroad locomotive 10 according to one or more embodiments. The locomotive includes a chassis (e.g., support frame) 20, which supports a diesel cycle engine 30. As explained below, the diesel cycle engine 30 may be a dual-fuel engine configured to combust a combination of natural gas and diesel. The engine 30 drives a driveshaft or a close coupling 40 that connects to an electric generator 50. The generator 50 connects via electrical wires 60 or other electrical conduits to electric motors 70 that drive the locomotive’s front wheels 80 and rear wheels 90.

The number of motor/wheel sets may be greater or lesser than the six illustrated in FIG. 1 (e.g. 2, 4, 8, 10). The wheels 80, 90 are mounted on front and rear bogies 100, 110, which, in turn mount to and support the chassis 20. A dual-fuel tank 200 mounts to an underside of the chassis 20 between the front and rear bogies 100, 110 and wheels 80, 90. Fuel lines 120, 130 connect the tank 200 to the engine 30 (e.g., either directly or indirectly via another intermediate structure such as a structure that mixes or conditions the fuels) to provide the fuels to the engine to power the locomotive 20.

The locomotive 20 comprises a variety of additional structures 140, which may include one or more of the following:

- an air compressor driven by the engine 30 to power the braking system of cars attached to the locomotive 20;
- sanding gear to increase friction between the wheels 80, 90 and the rails upon which the locomotive 20 is traveling;

- c. a control stand for the engineer operating the locomotive **20**;
- d. controls to enable the engineer to operate the locomotive **20**; and
- e. motor blower(s) to cool the motors **70**.

According to various non-limiting embodiments, the locomotive **10** comprises an EMD SD40-2 diesel-electric locomotive in which the conventional diesel fuel tank is removed and replaced with the dual-fuel tank **200**. The SD40-2's engine and fuel supply components are modified, as is well known in the art, to convert the locomotive's conventional diesel engine into the dual-fuel engine **30** of the locomotive **10**. According to various embodiments, a diesel-only locomotive can be retrofitted to convert it into a dual-fuel locomotive by replacing the conventional diesel fuel tank with the dual-fuel tank **200**. According to various embodiments, the retrofitting process is simplified because the tank **200** is shaped and configured to mount to a locomotive in place of a conventional diesel fuel tank that is disposed beneath the locomotive's chassis between the front and rear wheels. However, according to the alternative embodiments, the locomotive **10** is not a retrofit locomotive, but rather design built from the start to be a dual-fuel locomotive **10** without the tank **200**.

According to various embodiments, the locomotive **10** weighs at least 50,000, 100,000, 200,000, and/or 300,000 lbs. fully fueled. According to various embodiments, the locomotive **10** weighs less than 2,000,000, 1,000,000, and/or 500,000 lbs. fully fueled.

FIG. **17** illustrates a dual use ship **1700** according to one or more embodiments. The ship **1700** includes a hull **1701**, a superstructure **1702**, and a deckhouse **1703**. The ship **1700** includes a rudder **1704** for steering and one or more propellers **1705** for propulsion through water. The hull **1701** defines space for the dual-use fuel tank **200**, the dual-fuel engine **30** configured to combust a combination of natural gas and diesel and/or Bunker C, the electric generator **50**, and the motors **70**. Here, the motors **70** drive the propellers **1705** instead of wheels. These features are connected via components similar to the components of the locomotive **10** of FIG. **1**. More specifically, the engine **30** drives a drive-shaft or close coupling **40** that connects to an electric generator **50**. The generator **50** links via electrical wires **60** or other electrical conduits to one or more electric motors **70** that power the one or more propellers **1705**. The dual-fuel tank **200** supplies diesel and natural gas to the engine via the fuel lines **120**, **130**. It should generally be appreciated that when this disclosure refers to diesel, other fuels (e.g., No. 6, which is also known as Bunker C, Furnace Fuel Oil, FFO, or Residual Fuel Oil) are contemplated and may be substituted for the diesel. In various embodiments, the dual-fuel engine **30** of the dual use ship **1700** drives the propellers **1705** via a mechanical transmission and without the use of an electric generator **50** and/or a motor **70**.

According to various embodiments, the engine **30** comprises a diesel cycle engine that is configured to operate using a combination of diesel fuel (or Bunker C, as noted above) and natural gas. Such dual-fuel diesel cycle engines are known in the art. According to various embodiments, the engine **30** is an 8, 12, 16, and/or 20 cylinder engine. However, according to alternative embodiments, the engine **30** may comprise any other type of suitable internal combustion engine without deviating from the scope of the present invention (e.g., a spark-ignited OTTO cycle engine, etc.). According to various embodiments, the engine **30** is at least a 1,000, 2,000, 2,500, and/or 3,000 HP engine. Accord-

ing to various embodiments, the engine **30** has between 1,000 and 10,000 HP, and/or between 1,000 and 5,000 HP.

During dual-fuel operation of the engine **30**, natural gas is partially substituted for diesel fuel while the engine **30** performs the diesel cycle (or other cycle if Bunker C is used). Natural gas is separately conveyed from the diesel fuel (or Bunker C) and is provided to the engine's cylinders. During dual-fuel operation of the engine **30**, natural gas is mixed and combusted with the diesel fuel inside of the cylinders. The ratio of natural gas to diesel (or Bunker C) is known as the substitution rate. The typical substitution rate is near 0% (almost entirely diesel fuel or Bunker C) during idling, and approaches near 100% (almost entirely natural gas) at high engine load. Dynamic apportioning of fuel usage is accomplished with known technology (i.e., technology common in the dual-fuel engine marketplace).

The generator **50** may comprise any combination of suitable electrical components. For example, according to various embodiments, the generator **50** comprises an alternator, AC-to-DC rectifier, and a DC-to-AC inverter that drives AC motors **70**. According to other alternative embodiments, the generator **50** may comprise a DC generator that drives DC motors **70**. According to other embodiments, the generator **50** may comprise an AC alternator and AC-to-DC rectifier that drives DC motors **70**.

FIGS. **2-14** provide various views of the dual-fuel tank **200** that includes both a diesel fuel storage (i.e., vessels **500**, **510**) and compressed/pressurized natural gas storage (i.e., vessels **550**, **560**). Diesel fuel is loaded into vessels **500**, **510**, and compressed natural gas is loaded into vessels **550**, **560**. The locomotive **10** or the ship **1700** is then powered by a combination of diesel fuel and natural gas.

As shown in FIGS. **1**, **2** and **8**, the tank **200** comprises a frame **210** that enables the tank **200** to mount to the chassis **20** of the locomotive **10**. In the illustrated embodiment, the frame **210** includes a top plate **230** with a pattern of bolt holes **220** through which the tank **200** is bolted (via bolts **225**) to the chassis **20** of the locomotive **10** (see FIG. **8**).

As shown in FIGS. **2-14**, the frame **210** comprises:

- a. the top plate **230** (e.g., 1/2" thick plate) (see FIGS. **2**, **8**, **11**);
- b. lateral side plates **240** (e.g., 1/2" thick plate) (see FIGS. **2**, **4**, **8**, **11**);
- c. a bottom plate **250** (e.g., 1/2" thick plate) (see FIGS. **4**, **8**, **11**);
- d. curved internal plates **260** (e.g., 1/2" thick plate) (see FIGS. **11**, **13**);
- e. a central vertical plate **270** (e.g., 1/2" thick plate) (see FIGS. **11**, **13**);
- f. longitudinal reinforcement ribs **280**, **290**, **300** (e.g., 1/2" thick plate) (see FIGS. **11**, **13**);
- g. side supports **310** (e.g., 1/2" thick U-channel) (see FIGS. **11**, **13**);
- h. a fixed-end end plate **320** (e.g., 1" thick plate) (see FIGS. **4-6**);
- i. a floating-end end plate **330** (e.g., 1" thick plate) (see FIGS. **2**, **7**, **12**);
- j. floating-end end cap **340** (e.g., 1" thick plate) (see FIGS. **2**, **3**, **7**);
- k. end-cap mounting blocks **345** (see FIG. **7**);
- l. central lateral diesel tank gusset plates **350** (e.g., 1" thick plate with holes to permit diesel fuel passage therethrough and to lighten the plate) (see FIGS. **5**, **9**, **13**);

- m. distal lateral diesel tank gusset plates **360** (e.g., ½" thick plate with holes to permit diesel fuel passage therethrough and to lighten the plate) (see FIGS. **5**, **9**, **13**);
- n. central lateral gusset plates or stringers **370** (e.g., 1" thick plate) (see FIGS. **5**, **9**, **13**);
- o. distal lateral gusset plates **380** (e.g., ½" thick plate) (see FIGS. **5**, **9**, **13**); and
- p. locomotive mounting-reinforcement blocks **390** (e.g., machined or cast blocks) (see FIGS. **3**, **6**), through which the bolt holes **220** pass (see FIG. **6**).

As shown in the above-referenced figures, in the illustrated embodiment, the various plates **230**, **240**, **250**, **260**, **270**, **320**, **330**, **350**, **360**, **370**, **380**, ribs **280**, **290**, **300**, supports **310**, and blocks **345**, **390** comprise a strong material such as steel and are welded together along their lines of contact (or otherwise fastened together or integrally formed).

Two or more of the components of the frame **210** may be integrally formed. For example, according to various alternative embodiments, the top, side, and bottom plates **230**, **240**, **250** may comprise a single plate that is bent into the semi-tubular shape of the frame **210**.

As shown in FIGS. **9** and **11**, the top, side, bottom, and end plates **230**, **240**, **250**, **260**, **270**, **320**, **330** together define two diesel fuel vessels **500**, **510**, that generally each have the shape shown in FIG. **10**. Vessels **500**, **510** may be fluidly connected to each other or may be fluidly isolated from each other. As shown in FIGS. **1** and **5**, the fuel line **120** fluidly connects vessels **500**, **510** to the engine **30** to provide diesel fuel to the engine **30**. As shown in FIG. **11**, vessels **500**, **510** may be shaped to occupy the spaces between each of vessels **550**, **560** (discussed below) and the outer envelope of the tank **200**. According to various embodiments, vessels **500**, **510** collectively have a diesel fuel capacity of at least 500, 750, 1,000, 1,250, 1,500, 2,000, 2,500, and/or 3,000 gallons. According to various embodiments, vessels **500**, **510** collectively have a diesel fuel capacity of less than 20,000, 10,000, 9,000, 8,000, 7,000, 6,000, 5,000, 4,000, 3,000, 2,500, 2,250, and/or 2,000 gallons.

The dual-fuel tank **200** includes two compressed/pressurized natural gas vessels **550**, **560** that are inserted into central spaces **570**, **580** in the frame **210** (see FIGS. **11**, **12**) via openings **330a** in the end plate **330** (see FIG. **12**). As shown in FIG. **6**, vessels **550**, **560** are bolted or otherwise attached to the fixed-end end plate **320**. As shown in FIGS. **4** and **6**, the end plate **320** is reinforced via a round 1" thick reinforcing plate **590** and a plurality of gussets **600** to strengthen the connection between vessels **550**, **560** and the frame **210** via the end plate **320**.

On the opposite longitudinal end of the tank **200** (see FIGS. **2**, **3**, and **7**), a floating-end end cap **340** is bolted (or otherwise fastened) to the remainder of the frame **210** to enclose vessels **550**, **560** within the tank **200**. As shown in FIG. **7**, bolts **640** extend through holes in a main plate **630** of the end cap **340** and into mating bolt holes in the end plate **330** and reinforcement blocks **345** to secure the end cap **340** to the remainder of the frame **210**.

As shown in FIG. **7**, the end cap **340** comprises a main plate **630** and reinforcing rings **650** (e.g., 2" thick steel plates) that are welded or otherwise fastened to the plate **630**. The end cap **340** includes reinforcing gussets **660** that are welded or otherwise fastened to the plate **630** and rings **650**. The end cap **340** includes slider rings **670** that mount within holes defined in the main plate **630** and rings **650**. Mounting plates **680** (e.g., 2" thick steel plates) are fixed or

mounted to the slider rings **670**. Vessels **550**, **560** connect to the mounting plates **680** via bolts **690** or other suitable fasteners.

The end cap **340** permit a small degree of axial/longitudinal movement/float (i.e., along a longitudinal/axial direction of the tank **200** and vessels **550**, **560**) of the mounting plates **680** relative to the main plate **630**. This movement allows for the axial expansion and retraction of vessels **550**, **560** as they are pressurized and de-pressurized. The end cap **340** may facilitate such relative movement in any suitable way. For example, according to one or more embodiments, the inner portion of the slider rings **670** that mounts to the mounting plates **680** may deflect relative to the outer portion of the slider rings **670** that mount to the main plate **630** (e.g., similar to how a Belleville spring deflects). Alternatively, the slider rings **670** may rigidly connect to the mounting plates **680**, but slidingly translate along a central reference axis of each of the rings **650** (e.g., such that the plate **630** and rings **650** act as a bushing in which the slider rings **657** reciprocate).

According to various embodiments, the end cap **340** and end plate **320** form the only structural connection between vessels **550**, **560** and the remainder of the tank **200** (e.g., the frame **210**). As a result, vessels **550**, **560** do not physically contact the remainder of the tank **200** (i.e., do not physically contact the other internal features of the tank **200**) as vessels **550**, **560** axially expand and contract during use. Wear on vessels **550**, **560** is therefore reduced, which extends their useful life.

According to various embodiments, the tank **200** may be oriented with the end cap **340** longitudinal end (i.e., the end shown in the lower left in FIG. **2**) forward (i.e., to the left as shown in FIG. **1** and thus pointing in the same direction as the front of the locomotive **10** or ship **1700**). According to the various alternative embodiments, the tank **200** may be oriented with the end cap **340** longitudinal end (i.e., the end shown in the lower left in FIG. **2**) rearward (i.e., to the right as shown in FIG. **1** and thus pointing in the opposite direction as the front of the locomotive **10** or ship **1700**). According to various embodiments, the tank **200** is oriented such that the longitudinal axes of vessels **550**, **560** are generally oriented in the direction of travel of the locomotive **10** or ship **1700** (e.g. parallel to the railroad tracks upon which the locomotive **10** travels).

Vessels **550**, **560** may be any type of vessel that is suitable for storing a fuel. For example, vessels **550**, **560** may comprise compressed/pressurized natural gas vessels. Such compressed natural gas vessels may comprise any suitable material (e.g., steel, fiberglass, carbon fiber, etc.) and have any suitable shape (e.g., elongated cylinders with rounded ends) without deviating from the scope of the present invention. According to various embodiments, vessels **550**, **560** are generally cylindrical and have a diameter between 24 and 40 inches, e.g., 36 inches.

In a preferred embodiment, vessels **550**, **560** have the construction generally shown and illustrated in the cross section of FIG. **18**. More specifically, vessels **550**, **560** include a rubber bladder **1802** with an inner surface **1802b** and an outer surface **1802a**. As stated above, the rubber bladder **1802** may resemble an elongated cylinder with rounded (i.e., closed) ends. The inner surface **1802b** of the rubber bladder **1802** defines a void **1803** for storing CNG. The outer surface **1802a** of the rubber bladder **1802** is wrapped and fully enclosed in a winding **1801** with an inner portion **1801b** and an outer portion **1801a**. The winding



**1801** may comprise a cross-weave of aramid fibers and fiberglass. The cross-weave is optionally embedded in a resin matrix.

It should be appreciated that the architecture of the winding **1801** may be designed to minimize mechanical stress generated by large temperature gradients across the winding **1801**. During use, the CNG in the void **1803** will be at a low temperature, thus cooling the inner portion **1801b** of the winding **1801**. The outer portion **1801a** of the winding **1801** may be at a higher temperature. To minimize mechanical stress, the density of the winding **1801** may vary between the inner portion **1801b** and the outer portion **1801a**. In some embodiments, the inner portion **1801b** has a lower density than the outer portion **1801a**. In other embodiments, the inner portion **1801b** has a greater density than the outer portion **1801a**.

The winding **1801** offers advantages in addition to its high strength and structural integrity. First, because the winding **1801** is made of non-metallic material, the winding **1801** is robust against corrosion caused by Bunker C. More specifically, Bunker C typically contains sulfur and sulfur compounds that corrode and embrittle high-strength steels used in conventional CNG tanks. In various embodiments, the winding **1801** is made of any suitable material that does not react with sulfur (such as a cross-weave of aramid fibers and fiberglass optionally embedded in a resin matrix). Second, the winding **1801** is less dense (i.e., lighter than) high-strength steels. Thus, winding **1801**, as opposed to high-strength steels, improves the buoyancy of the ship **1700** and the fuel efficiency of the locomotive **10** by reducing the weight of the ship **1700** and the weight of the locomotive **10**. Third, the winding **1801** functions as a heat insulator, whereas high-strength steels are heat conductors. Therefore, the winding **1801** (as opposed to high-strength steel) discourages heat transfer between the void **1803** and the diesel fuel or Bunker C in vessels **500, 510**.

As stated above, the winding **1801** may include a cross-weave of aramid fibers and fiberglass embedded in a resin matrix. In some embodiments, the cross-weave also includes carbon fiber. It should be appreciated, however, and especially in marine applications (e.g., ship **1700**), carbon fiber may be disadvantageous and thus excluded from the winding **1801**. Besides being expensive, carbon fiber has an extraordinarily low density (i.e., is extremely light). During construction, marine vessels, such as the ship **1700**, are built to have a specific center of gravity and center of buoyancy. If these marine vessels are too light, then their center of gravity and center of buoyancy will shift from manufacturer specifications, thus presenting a capsizing risk. To reduce this risk and as stated above, embodiments of the winding **1801** specifically exclude carbon fiber. In various embodiments, the thickness and weight of the winding **1801** is adjusted via addition or removal of material to maintain the proper center of gravity and center of buoyancy of the ship **1700**. Although not shown in FIG. **17**, in various embodiments, vessels **550, 560** are wrapped or encased in a sacrificial layer for additional insulation. The sacrificial layer may be an extra layer of winding **1801**. The sacrificial layer may be any other suitable non-metallic and/or non-sulfur reactive material.

According to various embodiments vessels **550, 560** each store between 200 and 2,000 diesel-gallon-equivalent worth of compressed natural gas (DGE). According to various embodiments, the storage capacity of each vessel **550, 560** is each at least 100, 150, 200, 300, 400, 500, 600, 700, 800, 900, and/or 1000 DGE worth of compressed natural gas. According to various embodiments, the storage capacity of

each vessel **500, 560** is less than 5000, 4000, 3000, 2000, 1500, 1000, 900, 800, 700, and/or 600 DGE worth of compressed natural gas. According to various embodiments, vessels **550, 560** comprise Type 1, 2, 3, 4, and/or 5 vessels.

According to various embodiments, vessels **500, 510** have a combined diesel storage capacity of 1,000 gallons and vessels **550, 560** have a combined storage capacity of 1,200 DGE. According to other embodiments, vessels **500, 510** have a combined diesel storage capacity of 1,700 gallons and vessels **550, 560** have a combined storage capacity of 500 DGE.

As shown in FIG. **6**, vessels **550, 560** each comprise a port **550a, 560a** that fluidly connects to the fuel line **130**. In the illustrated embodiment, the fuel line **130** passes through holes in the fixed end plate **320**. However, according to various embodiments, the ports **550a, 560a** may be disposed in any other suitable location on vessels **550, 560** without deviating from the scope of the present invention (e.g., on the floating-end end cap **340** side of the tank **200**).

According to various embodiments, an operator refills the vessels through ports **550a, 560a** (or other suitable ports). During the refilling process, the pressure and thus the temperature of the CNG inside vessels **550, 560** will rise. As a consequence, the operator may be required to refill vessels **550, 560** in multiple stages. The operator waits for vessels **550, 560** to cool (and thus the pressure of CNG resident in vessels **550, 560** to reduce) in-between stages.

For example, the operator may perform a first stage of refilling where the temperature and pressure of the CNG rises to 70 degrees Celsius and 400 psi. The operator may then wait for twelve hours for the CNG to cool to 40 degrees Celsius and reduce in pressure to 300 psi. The operator then performs the second stage of refilling, which raises the temperature of the CNG back to 70 degrees Celsius and 400 psi etc. To expedite the refilling process, the operator may control the rate of CNG flow into vessels **550, 560** based on a measured temperature and/or pressure of the CNG resident in vessels **550, 560**. Proper control enables the operator to refill vessels **550, 560** in a single stage.

As shown in FIG. **1**, the locomotive **10** includes one or more heaters **750** that heat the natural gas before entering the engine **30**. The heater **750** is powered by onboard utilities of the locomotive **10**. For example, the heater **750** may use heat from the engine **30** itself or the motors **70** (e.g., via a heat exchanger) and/or may be powered by the locomotive's electrical supply (e.g., via resistive heating, a heat pump, etc.). The heater **750** may ensure that the natural gas remains at a safe working temperature (e.g., avoiding cryogenic conditions that could damage components not designed to handle cryogenic conditions, keeping the natural gas above  $-40^{\circ}\text{C}$ ). According to various embodiments, the heater **750** may heat natural gas after the natural gas has left the tank **200** (e.g., in the fuel line **130**). Alternatively, the heater **750** may heat the compressed natural gas within the tank **200**. Heating the natural gas within the tank **200** (e.g., within vessels **550, 560**) may help to maintain the pressure in vessels **550, 560**, which may provide for more complete unloading of the natural gas in vessels **550, 560**.

Similarly, the ship **1700** includes one or more heaters (not shown) configured to heat the natural gas and/or the residual fuels stored in vessels **500, 510**. In various embodiments, the heaters are configured to heat the natural gas to a first temperature and the diesel (as stated above, when this disclosure refers to diesel, other fuels such as Bunker C are contemplated) to a second temperature. More specifically, residual fuels such as Bunker C must be heated to a viscosity suitable for fuel injectors (not shown) of the engine **30**. In

various embodiments, the Bunker C is stored in the tank **200** at 40 degrees Celsius, then heated to 120 degrees Celsius prior to entering the fuel injectors of the engine **30**. The Bunker C can be heated directly in the tank **200** or while it passes through the fuel line **120**. It should thus be appreciated that the viscosity of the Bunker C may be high while resident in the tank **200** and low while resident in the fuel line **120**.

While the tank **200** is illustrated and described as having various particular structures (e.g., a variety of plates, ribs, gussets, etc.), various of these structures may be omitted without deviating from the scope of the present invention. For example, various reinforcing structures (e.g., ribs, blocks, etc.) may be removed or added, depending on the particular design goals of a particular dual-fuel tank, without deviating from the scope of the present invention.

The tank **200** is designed to withstand significant side impacts without rupturing diesel vessels **500**, **510** or the compressed natural gas vessels **550**, **560**. According to various embodiments, the CNG vessels **550**, **560** are disposed laterally inwardly from the diesel vessels **500**, **510** (see FIG. **11**). As a result, side impacts on the tank **200** will be absorbed by the diesel vessels **500**, **510** (and the fuel therein) and frame **210**, which mitigates side-impact force experienced by the CNG vessels **550**, **560**. According to various embodiments, disposing the CNG vessels **550**, **560** in a more laterally central location than the diesel vessels **500**, **510**, the tank **200** may be able to withstand larger side impact loads without rupturing the vessels **500**, **510**, **550**, **560** than would otherwise be possible. As shown in FIGS. **2-14**, additional strengthening members (e.g., the side supports **310**, the ribs **280**, **290**, **300**) are added to the frame **210** of the tank **200** to further improve tank **200** resistance to side impacts.

As shown in FIG. **11**, vessels **500**, **510** extend generally outward (i.e., relative to the lateral center-line of the locomotive **10** that is generally co-planar with the central plate **270**) farther than the laterally-outward-most portion of vessels **550**, **560**.

According to various embodiments, the plates **230**, **240**, **250**, **260**, **320**, **330** and other structures that define the diesel vessels **500**, **510** may be strengthened beyond the strength required for the diesel vessels **500**, **510** themselves to withstand side-loads. Such strengthening may enable the diesel vessels **500**, **510** to act as outer frames that protect the centrally disposed CNG vessels **550**, **560**. Thus the structural reinforcement to protect the CNG vessels **550**, **560** may be integrated into the diesel vessels **500**, **510**. According to various embodiments, use of the diesel vessels **500**, **510** as structural protection for the CNG vessels **550**, **560** may reduce the overall cost of the tank **200**. According to various alternative embodiments, vessels **550**, **560** may be strengthened such that they are as strong as or stronger than the diesel vessels **500**, **510**.

According to various embodiments, the curved internal plates **260**, as shown in FIG. **12** extend longitudinally through the dual-fuel tank **200**. These plates, in conjunction with plates **240** define vessels **500** and **510**. As stated above, in various embodiments, the curved internal plates **260** are absent, enabling fuel in vessels **500**, **510** to contact vessels **550**, **560**.

Consequently, various embodiments of the tank **200** (and below discussed tanks **1200**, **2200**) provide the locomotive **10** with a safe and reliable fuel supply that will comply with U.S. Federal Railway Administration and Association of

American Railroads requirements S-580, S-5506 respectively and/or newly developed AAR natural gas tender crashworthiness rules.

FIG. **15** is a diagrammatic cut-away view of a dual-fuel tank **1200** according to an alternative embodiment. The tank **1200** is generally similar to the tank **200**, except that the tank **1200** comprises three compressed natural gas vessels **1210**, **1220**, **1230**, rather than two. The diesel fuel vessel(s) **1240** is spread out between the various gaps between the natural gas vessels **1210**, **1220**, **1230**.

The tank **1200** also differs from the tank **200** in another way. While the CNG vessels **550**, **560** of the tank **200** were isolated from (i.e., not in direct contact with) the diesel fuel in vessels **500**, **510** by the intermediate plates **260**, the vessels **1210**, **1220**, **1230** are disposed inside of the diesel fuel vessel **1240** and directly contact the diesel fuel in the vessel **1240**. According to various embodiments, the tank **200** may be modified in a similar manner such that vessels **550**, **560** are disposed within vessels **500**, **510** and directly contact the diesel fuel in the tank **200**. The tank **1200** reduces the empty space within the tank **1200** by expanding the diesel fuel vessel **1240** to use a large portion of the tank **1200** space that is not taken up by the CNG vessels **1210**, **1220**, **1230**.

FIG. **16** is a diagrammatic cut-away view of a dual-fuel tank **2200** according to an alternative embodiment. The tank **2200** is generally similar to the tank **200**, except that the tank **2200** comprises a single natural gas vessel **2210**, rather than two. As shown in FIG. **16**, the vessel **2210** may house pressurized cylinders (e.g., vessels **550**, **560**). Alternatively, the vessel **2210** may be directly filled with CNG. The vessel **2210** has a non-cylindrical cross-section that more closely conforms to the cross-sectional shape of the overall tank **2200**. According to various embodiments, the vessel **2210** has a compressed natural gas storage capacity of at least 500, 600, 700, 800, 900, 1,000, 1,100, 1,200 and/or 1,300 DGE. According to various embodiments, the vessel **2210** has a compressed natural gas storage capacity of less than 5,000, 4,000, 3,000, 2,000, and/or 1,000 DGE. The vessel **2210** may include internal support structures that help it to retain its strength when under pressure. The diesel fuel vessel(s) **2220** is disposed laterally-outward of (and below according to various embodiments) the vessel **2210**. In embodiments where the vessel **2210** houses pressurized cylinders, the vessel **2210** may, as shown in FIG. **16**, extend from a top of the tank **2200** and directly attach to the underside of the chassis **20**.

Relative to a comparably sized conventional diesel fuel tank for a locomotive and/or ship, the tank **200**, **1200**, **2200** may provide less overall energy (e.g., if the energy density of the natural gas is lower than the energy density of diesel fuel (on a volume basis)). However, the tank **200** may be more cost-efficient in view of the relative price of natural gas and diesel fuel. According to various embodiments, the dual-fuel locomotive **10** and/or the dual-fuel ship **1700** may be advantageous for short-haul or local runs that permit more frequent refueling than relatively longer-haul runs. In such short-haul runs, the capacity of a conventional diesel-only fuel tank may already exceed the energy requirements of the short-haul distance between refueling. As used herein, the term "short-haul" includes local locomotives, yard locomotives that generally remain in one geographic area and move railroad cars around and between tracks, and short and regional railroad lines. In these and other situations, the dual-fuel tank of the locomotive **10** and/or the ship **1700** may reduce fuel costs. According to various embodiments, the dual-fuel tank of the locomotive **10** and/or the ship **1700**

facilitates the dual-fuel operation of the locomotive **10** and/or the ship **1700** without using a separate fuel tender.

In the illustrated tanks **200**, **1200**, **2200**, the CNG vessels **550**, **560**, **1210**, **1220**, **1230**, **2210** are in close proximity to and/or in direct contact with the diesel fuel (or, as explained above, Bunker C) in the diesel fuel vessels **500**, **510**, **1240**, **2220**. Such close proximity or contact may facilitate heat transfer between the diesel fuel and the compressed natural gas in the CNG vessels. Such heat transfer may reduce the extent to which the natural gas cools as it is unloaded from the vessels as the locomotive **10** uses fuel. The tanks **200**, **1200**, **2200** may therefore help to avoid cryogenic gas conditions. Conversely, such heat transfer may reduce the extent to which the natural gas heats up as it is loaded into the vessels during refueling.

In the illustrated embodiments, the fuel vessels **500**, **510**, **1240**, **2220** are diesel fuel tanks. However, according to alternative embodiments, these vessels may be designed to store and store any other type of fuel (e.g., other liquid fuel, ethanol, methanol, gasoline, Bunker C, etc.) without departing from the scope of the present invention. According to various embodiments, the vessels **500**, **510**, **1240**, **2220** are ambient pressure vessels that are generally designed to store fuel at the ambient environment pressure (e.g., within 30, 20, 10, and/or 5% of the ambient pressure in absolute pressure terms, within 50, 40, 30, 20, and/or 10 psi of the local ambient pressure).

In the illustrated embodiments, the vessels **550**, **560**, **1210**, **1220**, **1230**, **2210** are compressed natural gas vessels. However, according to alternative embodiments, these vessels may be designed and configured to store any other suitable type of fuel (e.g., other compressed/pressurized fuel gasses, liquid natural gas, propane, adsorbed natural gas (ANG), in hydrate form natural gas (HNG), etc.).

Natural gas filling stations of the type described in PCT Publication Nos. WO2014/031999 and/or WO2014/153110 (both of which are hereby incorporated by reference in their entirety) may be use or sold with the tanks **200**, **1200**, **2200** to facilitate loading of compressed natural gas into vessels **550**, **560**.

The foregoing illustrated embodiments are provided to illustrate the structural and functional principles of embodiments of the present invention and are not intended to be limiting. To the contrary, the principles of the present invention are intended to encompass any and all changes, alterations and/or substitutions within the spirit and scope of the following claims.

The invention claimed is:

**1.** A dual-fuel railroad locomotive comprising:

a chassis;

a plurality of railroad wheels mounted to the chassis;

a dual-fuel diesel cycle engine supported by the chassis and operatively connected to the wheels to drive the wheels to propel the locomotive along a railroad track;

and

a dual-fuel tank mounted to the chassis and in fluid communication with the dual-fuel diesel cycle engine, the dual-fuel tank including:

at least one liquid fuel vessel, and

at least one pressurized fuel vessel,

wherein the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts.

**2.** The locomotive of claim **1**, wherein the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel.

**3.** The locomotive of claim **1**, wherein the at least one liquid fuel vessel extends laterally outwardly farther than any portion of the at least one pressurized fuel vessel.

**4.** The locomotive of claim **1**, wherein the at least one liquid fuel vessel includes at least one diesel fuel vessel.

**5.** The locomotive of claim **1**, wherein the at least one pressurized fuel vessel includes at least one compressed natural gas vessel.

**6.** The locomotive of claim **1**, wherein the at least one liquid fuel vessel includes a void at least partially defined by a frame of the chassis.

**7.** The locomotive of claim **1**, wherein the dual-fuel tank further includes at least one plate, the at least one plate including a first surface and a second surface opposing the first surface, wherein at least a portion of the at least one liquid fuel vessel directly contacts at least a portion of the first surface, and at least a portion of the at least one pressurized fuel vessel directly contacts at least a portion of the second surface.

**8.** A method of converting a railroad locomotive into a dual fuel locomotive, the method comprising:

removing a single-fuel tank from the railroad locomotive; and

mounting a dual-fuel tank to the railroad locomotive in place of the single-fuel tank, the dual-fuel tank including: at least one liquid fuel vessel and at least one pressurized fuel vessel,

wherein the at least one liquid fuel vessel is positioned to form a side-impact buffer that protects the at least one pressurized fuel vessel from side-impacts after said mounting.

**9.** The method of claim **8**, further comprising, after said mounting, operatively connecting the at least one liquid fuel vessel and the at least one pressurized fuel vessel to the railroad locomotive so that the locomotive can be powered by fuel in the at least one liquid fuel vessel and the at least one pressurized fuel vessel.

**10.** The method of claim **8**, wherein the at least one liquid fuel vessel includes a diesel fuel vessel.

**11.** The method of claim **8**, wherein the at least one pressurized fuel vessel includes a natural gas vessel.

**12.** The method of claim **8**, wherein the at least one liquid fuel vessel is disposed at least partially laterally outwardly from the at least one pressurized fuel vessel after said mounting.

**13.** A dual-fuel tank comprising:

a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels;

wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that each of the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame,

wherein the frame includes a first end plate and a second end plate and both of the first end plate and the second end plate support the pressurized fuel vessels.

**14.** The tank of claim **13**, wherein the liquid fuel vessels include voids at least partially defined by the frame.

**15.** The tank of claim **14**, wherein the voids are at least partially defined by curved internal plates longitudinally extending inside the frame.

**16.** The tank of claim **15**, wherein the curved internal plates are C-shaped and form a barrier between the liquid fuel vessels and the pressurized fuel vessels.

**17.** The tank of claim **13**, including at least one fuel line in fluid communication with each of the vessels, and at least one of the fuel lines includes an electric heater configured to heat the fluid flowing therethrough.

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18. The tank of claim 13, wherein the first end plate and the second end plate cooperate to suspend at least one of the pressurized fuel vessels inside of the frame such that said pressurized fuel vessel is only supported by the first end plate and the second end plate.

19. The tank of claim 13, wherein the first end plate defines at least one longitudinally extending central ring void.

20. The tank of claim 19, including a slider ring slideably received in the at least one longitudinally extending central rings void, the slider ring being fixed to an end of one of the pressure vessels.

21. The tank of claim 13, wherein at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer.

22. The tank of claim 21, wherein the non-sulfur reactive layer includes a winding that includes a cross-weave of aramid fibers and fiberglass.

23. The tank of claim 22, wherein the winding excludes carbon-fiber.

24. The tank of claim 21, wherein the at least one of the pressurized vessels includes a non-sulfur reactive insulator encasing the non-sulfur reactive layer.

25. A vehicle including an engine and the dual-fuel tank of claim 13, wherein the engine is configured to draw and combust fuel from each of the liquid fuel vessels and the pressurized fuel vessels.

26. The vehicle of claim 25, wherein the engine is configured to vary the ratio of combusted liquid fuel to the ratio of combusted pressurized fuel.

27. A ship comprising:

a dual-fuel engine configured to draw both liquid fuel and pressurized fuel from the dual-fuel tank of claim 13.

28. The ship of claim 27, wherein the liquid fuel vessels include Bunker C fuel.

29. The ship of claim 28, which includes a heater configured to lower the viscosity of the liquid fuel while the liquid fuel is drawn from the dual-fuel tank to the dual-fuel engine.

30. The ship of claim 27, wherein at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer, and wherein the non-sulfur reactive layer is a winding that includes a cross-weave of aramid fibers and fiberglass, the winding has an inner portion and an outer portion, and a density of the inner portion is different than a density of the outer portion.

31. A dual-fuel tank comprising:

a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels;

wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that each of the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame,

wherein the liquid fuel vessels include voids at least partially defined by the frame, wherein the voids are at least partially defined by curved internal plates longitudinally extending inside the frame, and

wherein the curved internal plates are C-shaped and form a barrier between the liquid fuel vessels and the pressurized fuel vessels.

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32. A dual-fuel tank comprising:

a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels;

wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that each of the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame,

wherein at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer.

33. The tank of claim 32, wherein the non-sulfur reactive layer includes a winding that includes a cross-weave of aramid fibers and fiberglass.

34. The tank of claim 33, wherein the winding excludes carbon-fiber.

35. The tank of claim 32, wherein the at least one of the pressurized vessels includes a non-sulfur reactive insulator encasing the non-sulfur reactive layer.

36. A vehicle including:

an engine; and

a dual fuel tank, the dual-fuel tank comprising:

a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels,

wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that each of the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame,

wherein the engine is configured to draw and combust fuel from each of the liquid fuel vessels and the pressurized fuel vessels, and

wherein the engine is configured to vary the ratio of combusted liquid fuel to the ratio of combusted pressurized fuel.

37. A ship comprising:

a dual-fuel engine configured to draw both liquid fuel and pressurized fuel from a dual-fuel tank, the dual-fuel tank comprising:

a frame housing one or more liquid fuel vessels and one or more pressurized fuel vessels;

wherein the pressurized fuel vessels are disposed laterally inward of the liquid fuel vessels such that each of the liquid fuel vessels protect the pressurized fuel vessels from a lateral impact to the frame.

38. The ship of claim 37, wherein the liquid fuel vessels include Bunker C fuel.

39. The ship of claim 38, which includes a heater configured to lower the viscosity of the liquid fuel while the liquid fuel is drawn from the dual-fuel tank to the dual-fuel engine.

40. The ship of claim 37, wherein at least one of the pressurized vessels includes an inner rubber bladder encased in a non-sulfur reactive layer, and wherein the non-sulfur reactive layer is a winding that includes a cross-weave of aramid fibers and fiberglass, the winding has an inner portion and an outer portion, and a density of the inner portion is different than a density of the outer portion.

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